DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 729

OIL SHALE OF THE ROCKY MOUNTAIN REGION

BY

DEAN E. WINCHESTER

WASHINGTON
GOVERNMENT PRINTING OFFICE
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INTRODUCTION.

During the last few years public attention has been repeatedly called to the rapidly increasing demand for petroleum and its products and the inability of the American producer to keep pace with this demand. Vigorous attempts have been made to increase the output of the known oil fields and to locate new areas from which to pump liquid petroleum, and the chemist has tried to develop a substitute for it, but still the demand increases more rapidly than the production. Long ago Scotland faced a lack of oil and found it possible to develop a supply by the distillation of her oil shales. To-day the oil shales of the United States are being investigated in the hope that in the near future they may materially assist in furnishing the liquid fuels needed in our industries. Much has already been done toward placing the American oil-shale industry on a firm, economical basis, but a still greater amount of chemical and engineering research is needed before it can be said that the industry is assured of success, and a long time must elapse before the output of shale oil will be sufficiently large to affect materially the total production of liquid hydrocarbon fuels in the United States.

In the United States it is possible to derive oil from rock of several different types. Most of the petroleum that is being produced to-day is obtained by penetrating reservoir sandstones and shales and then pumping out the oil or allowing it to flow out under pressure provided by nature. In these sandstones and shales free oil exists in the pores and cavities of the rock.

Oil shale, on the other hand, does not contain oil that may be extracted by mechanical means, but contains an abundance of partly bituminized organic matter that can be converted into oil by heating. Preliminary studies of the subject indicate that only certain types of organic material are capable of yielding when heated liquid oil lighter than water; others when heated in the same manner give heavy tar products many of which are heavier than water. Even the richest of the American oil shales show only a very small amount of free oil when subjected to the action of the ordinary solvents of

hydrocarbon substances, but when these shales are heated oils very similar to petroleum are produced and driven off in the form of vapors, which may be condensed into liquid shale oil.

The shales of the Rocky Mountain region have been the subject of a considerable amount of study by geologists of the United States Geological Survey, and several reports on them have been printed, but most of these reports, although several times reprinted, are no longer available for distribution. Therefore in the present report an attempt is made to include all of this information, together with that collected by the writer and others since the publication of the last previous report on oil shale.

FIELD WORK.

HISTORY AND METHODS.

The field work upon which this report is based was started in 1913 by E. G. Woodruff and D. T. Day,[1] assisted in the field by W. P. Woodring, and continued by the writer,[2] assisted by H. M. Robinson, W. B. Wilson, and H. R. Bennett, each season up to and including the season of 1918. C. F. Bowen [3] in 1916 made a preliminary examination of oil shales in southwestern Montana, and E. T. Hancock in 1917 collected several samples in west-central Montana, data concerning which are included by D. D. Condit [4] in his report on the phosphatic oil shales of the mountain region based on field studies made in 1918. J. P. Buwalda studied the oil-yielding shales of Nevada in 1918, and the data he obtained, which have not yet been published, are summarized in this report. From time to time other geologists of the United States Geological Survey have collected samples of shale and coal from the Rocky Mountain region, and the results of distillation of these samples have been published as information worthy of printed record.[5] Chemical research has been carried on by Chase Palmer, Theodore Erickson, and others in the laboratories of the Geological Survey and by David T. Day, C. R. Bopp, Martin Gavin, and others in the laboratories of the Bureau of Mines. Much of the information has already been printed but is distributed through several volumes, so that a study of the Geological Survey's information on oil shale in this region requires the acquisition of many separate reports, some of which are difficult to get.

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[1] Woodruff, E. G., and Day, D. T., Oil shales of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 581, pp. 1–21, 1914.

[2] Winchester, D. E., Oil shale in northwestern Colorado and adjacent areas: U. S. Geol. Survey Bull. 641, pp. 139–198, 1916; Oil shale of the Uinta Basin, northeastern Utah, and Results of dry distillation of miscellaneous shale samples: U. S. Geol. Survey Bull. 691, pp. 27–55, 1918.

[3] Bowen, C. F., Phosphatic oil shales near Dell and Dillon, Beaverhead County, Mont.: U. S. Geol. Survey Bull. 661, pp. 315–320, 1917

[4] Condit, D. D., Oil shale in western Montana, southeastern Idaho, and adjacent parts of Wyoming and Utah: U. S. Geol. Survey Bull. 711, pp. 15–40, 1919.

[5] Winchester, D. E., op. cit. (Bull. 691), pp. 51–55.

The work by Woodruff and Day consisted in a preliminary examination of the formations containing oil shale at several widely separated localities in Colorado and Utah, and the testing of 11 samples of the shale to determine the amount of oil and other products that can be obtained from it. This was followed by the writer's investigations, in which the oil shale has been mapped and studied in more or less detail along its entire outcrop in Colorado, Utah, and that portion of southwestern Wyoming south of the Union Pacific Railroad and west of Green River. During these studies many stratigraphic sections of the Green River formation have been examined, and more than 350 samples of shale have been distilled. The mapping has been done largely by plane-table methods, and the accompanying maps are compiled largely from the data thus obtained.

Reports of rich oil shale in Montana resulted in preliminary investigations by C. F. Bowen in the southwestern part of the State in the fall of 1916, the results of which were published soon afterward, and in 1917 E. T. Hancock examined shale outcrops in the region south of Great Falls. The results of these two examinations were sufficiently interesting to warrant further work, and in 1918 D. D. Condit made a reconnaissance study of the black shales of the Phosphoria (Permian) and associated formations of the whole northern Rocky Mountain region. During this work shales associated with the phosphate-bearing rocks were examined in Montana, Idaho, Utah, and Wyoming, and about a hundred samples were distilled for oil. Many of the samples were also analyzed for nitrogen and for phosphorus.

J. P. Buwalda spent a large portion of the field season of 1918 studying in detail the Tertiary oil shales in northeastern Nevada, especially near Elko, where steps have recently been taken to commercialize the shales. He collected and tested samples, studied and mapped shale outcrops, and made a thorough study of the general conditions which are of interest in view of the possible establishment of an oil-shale industry in that vicinity in the near future.

The oil-shale fields of the Rocky Mountain region are shown on Plate I.

TESTING APPARATUS.

At the very beginning of the oil-shale investigations by the geologists of the Geological Survey it was realized that the field men could carry on their investigations much more intelligently if they knew, while in the field, how much oil would be yielded by material of any particular type when distilled, and an apparatus that could be operated in the field by the geologist was therefore designed. The first outfit was not perfect, but the results of the first two years' experiments furnished data upon which to base the construction of a

field testing outfit which has proved very satisfactory, and according to comparative tests recently made by the Bureau of Mines the careful use of this outfit gives results which are not far divergent from the results that may be expected when the same shales are treated in a commercial-sized retort such as that used in the oil-shale industry of Scotland.

LARGE DISTILLING APPARATUS.

Woodruff and Day in the first season's work (1913) used a large apparatus which necessitated the mining of a sample of shale weighing 100 pounds or more and which required from seven to eight hours for each test run. The retort into which the shale was charged consisted of a section of 12-inch iron casing pipe 4 feet long, having flanges screwed on the ends and a removable iron plate with asbestos gaskets fitted to each flange. On one side of the retort were fitted a small steam dome, a pressure gage, and a safety valve. From the top of the dome a pipe led to a block-tin condensing coil in a small water-filled tank. The coil discharged into Wolff bottles set in series and provided with stopcocks so that the liquids could be drawn off without interfering with the operation of the condenser. During the operation the retort was suspended by iron supports in a narrow trench cut in the ground, covered with iron plates and earth, and a flue erected at the back. Heat was obtained from a wood fire placed under the retort.

In the distilling operation the head plate was removed, the retort charged with shale broken into pieces not larger than 4 inches in diameter, the head plate replaced, fire started to give a gentle heat at first and gradually increased until the lower part of the retort became red hot, then held constant until near the end of the operation, when it was increased for a short time and then allowed to subside. The products obtained were water vapor, gas, oil and gas, and finally only gas in the order named. From seven to eight hours' heating was required for a charge.

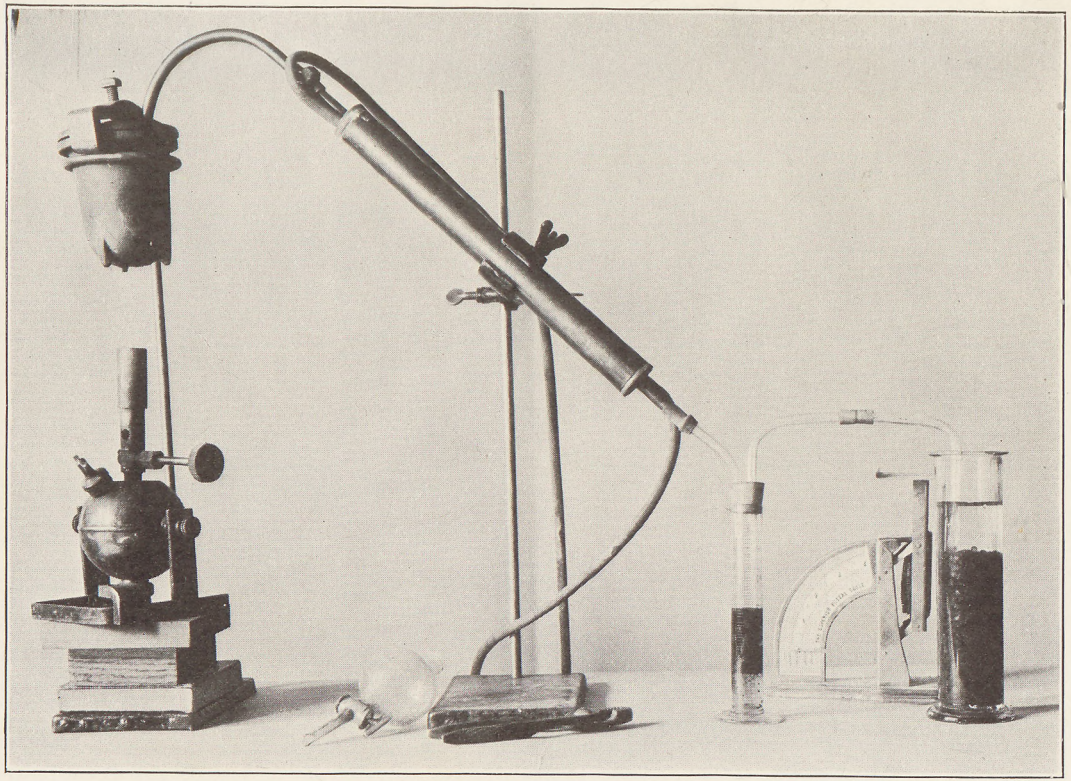
SMALL DISTILLING APPARATUS.

The apparatus described above, being large and not easily transported and eventually becoming unfit for use through leakage, was abandoned and replaced by a still which required a sample weighing only about 1 pound and which was heated by gasoline torches. With two of these smaller distilling outfits four samples of shale were tested easily in one working day, whereas only one sample of shale a day could be tested with the larger apparatus.

The distilling apparatus used in 1915 (see Pl. II), which is similar to that used during the later part of the 1914 season but much more compact and lighter, consists of the following essential parts:

MAP OF THE ROCKY MOUNTAIN REGION, SHOWING OIL-SHALE FIELDS.

Heavy lines indicate areas shown on larger-scale maps.



FIELD APPARATUS FOR DISTILLING OIL SHALE

POCKET TESTING APPARATUS FOR ESTIMATING RICHNESS OF OIL SHALE.

Two Barthel gasoline blast lamps.
One half-pint iron mercury retort, with delivery tubes.
One brass condenser.
Two ring stands.
One 3½-inch ring.
One large condenser clamp.
One receiver for condensed liquids (50 cubic centimeter glass graduate).
One ammonia scrubber (8-ounce bottle filled with glass beads).
Two pairs combination pliers.
One postal balance.
6 feet of rubber tubing.
Glass tube for connecting condenser, receiver, and ammonia scrubber.
One glass separatory funnel.

A battery of four of these retorts can be operated by a single person without inconvenience, and the retorts with all necessary equipment such as condensers, burners, supports, a small iron mortar for crushing the shale, and a balance, can easily be packed in a box 1 foot deep, 18 inches wide, and 3 feet long.

Because of its simplicity and because its flame can be adjusted to any desired angle or length, the Barthel blast lamp was chosen to furnish heat for the still. This lamp consists of a small spherical gasoline tank with burner, mounted on an iron base in such a way that the burner may be turned at any angle. To manipulate the burner the tank is first filled nearly full of gasoline and the cap securely screwed down. Gasoline is placed in the small cuplike depression around the burner and lighted. When this gasoline is burned out, sufficient heat will have been produced to generate gas under pressure, which may be lighted at the end of the burner on opening the burner valve. If the flame is yellow or sputters the burner is not sufficiently hot and must be reheated. The gasoline tank of each burner holds sufficient fuel to keep the blast burning about two hours. Inasmuch as each distillation of shale requires from three to four hours, two burners are used with each retort. The second burner may be most easily lighted by playing the flame of the first on it.

Inasmuch as the Barthel lamp is of foreign make and could not be obtained during the war, it was necessary to substitute other apparatus for heating the retorts. An ordinary plumber's torch with a stand so adjusted that the flame may be directed upward may be used, or a more elaborate equipment, consisting of self-heating burners with connection to a gasoline pressure tank, makes a very satisfactory combination.

The vessel in which the shale is to be heated is an ordinary half-pint iron mercury retort, which is equipped with close-fitting lid and clamp and an iron delivery tube. The delivery tube is fastened to the inner tube of the condenser by a small brass plumber's union, which provides a very easily disconnected joint. The retort is held in place above the flame of the burner by a ring and ring stand.

The condenser used in the outfit consists of an inner tube of thin brass three-eighths of an inch in diameter and 15 inches long, to one end of which is soldered a small brass plumber's union. This inner tube is surrounded by a second thin-walled brass tube 1¼ inches in diameter and 11 inches long, which is provided with a two-hole rubber stopper at each end, one hole being for the inner tube and the other for a small brass tube 2 inches long to provide connection for the entrance and waste of the water which is circulated between the inner and outer tubes to keep the inner tube cool. The delivery tube from the retort is so bent that when the retort is in an upright position the condenser will be turned at an angle of about 40° from the horizontal. The condenser is held in position by a single clamp, attached to a ring stand.

The water for cooling the condenser may be had from waterworks, or if no running water is at hand a tank or tub may be stationed near the condenser, at a slightly higher level, and the water conveyed over the top by a siphon entering the condenser at the lower end and wasting at the upper end.

The receiver for the condensable products of the distillation consists of a 50 cubic centimeter glass graduate, provided with a two-hole rubber stopper, through which are thrust two glass tubes, one for the entrance of the liquids and permanent gases from the condenser and the other for the escape of the permanent gases to the ammonia scrubber. The glass tubes have a diameter of about a quarter of an inch and are bent at the proper angles to make connections with the condenser and scrubber. The tubes should barely penetrate the cork.

The ammonia scrubber consisted of an ordinary glass cylinder or 8-ounce wide-mouthed bottle, provided with a glass tube reaching nearly to the bottom of the bottle for the entrance of permanent gas from the receiver. The bottle is filled with glass beads, which provide additional surface and a means of breaking up the gas into small bubbles as it passes up through a 10 per cent solution of sulphuric acid. It was found after some experimental work that the determination of the ammonia as described above was not satisfactory, inasmuch as a considerable part of the nitrogen in the shale is not converted into ammonia until after all the oil is driven off and higher temperatures are reached, and there is a tendency on the part of the operator to discontinue the distillation as soon as oil ceases to be evolved. During the last two seasons' work, therefore, no attention was paid in the field to products other than oil, and it was thus possible to eliminate the ammonia scrubber. In this work 2-ounce samples of the shale were sent to the chemical laboratory for total nitrogen determinations, from which the theoretical number of pounds of ammonium sulphate that can be obtained from a ton of

shale is computed by simply multiplying the percentage of nitrogen by the factor 94.2.

The pliers are used for handling the retort, the postal balance to weigh the sample of shale, and the glass separatory funnel to separate the oil from the water derived from the shale.

In order to determine the quantity of oil that may be derived from a sample of shale the shale is first pulverized to pass through a screen of ½-inch mesh. After thorough mixing a sample weighing 8½ ounces is so selected as to represent the entire quantity. This sample is placed in the iron retort and the cover is securely fastened. In order to prevent leaks the joint between the cover and retort bowl is plastered with a thick paste made of a mixture of powdered graphite and glycerine, or in case of necessity lampblack and vaseline may be used. The delivery tube from the retort is then coupled with the inner tube of the condenser, and cool water (not ice water) is started circulating through the condenser. The blast lamp is then lighted and placed beneath the retort, with the flame turned as low as possible. After heating about 10 minutes water and oil will begin to condense and be delivered into the receiver. Gentle heat should be applied to the retort as long as any oil is delivered to the receiver, then the flame of the burner may be lengthened until at the end of three or four hours the burner will be at full blast, the retort will be red-hot, and the shale will cease to yield either oil or gas. The products of the distillation are then measured; the quantity of oil and the quantity of water in the receiver are recorded. The yield of oil in United States gallons to the short ton of shale is equal to the number of cubic centimeters of oil in the receiver, provided the sample of shale used weighs 8½ ounces. The oil obtained from the distillation should be placed in a small bottle for the determination of its specific gravity, which can best be made in the laboratory.

POCKET TESTING APPARATUS.

In some of the work it has not been practicable to carry the quantitative testing apparatus into the field, but it has been found possible to make rough estimates of the richness of shales by the use of a small alcohol torch and a glass test tube. (See Pl. III.) This outfit is so simple and the data furnished by its use are so valuable that no geologist interested in the study of sedimentary rocks can afford to work without it in his field kit.

The outfit consists of a Hess soldering torch which burns alcohol and several glass tubes 4 or 5 inches long by three-eighths of an inch in diameter and closed at one end. The torch is for sale by Hess & Son, 2910 North Sixteenth Street, Philadelphia, Pa., and by some hardware stores in the larger cities. In making a test for oil or oil-forming substances about 1 gram of powdered rock is placed in the

bottom of the glass test tube and heated to redness. The presence of oil or oil-forming substances is shown by the evolution of white or yellow-brown fumes, and the richness of the sample is indicated by the relative quantity of oil condensed on the cool walls of the glass tube away from the flame. This apparatus provides a means of determining in the field whether shale will yield much or little oil, and with practice the operator will find it possible to estimate the richness of shale within 15 or 20 per cent of the true value.

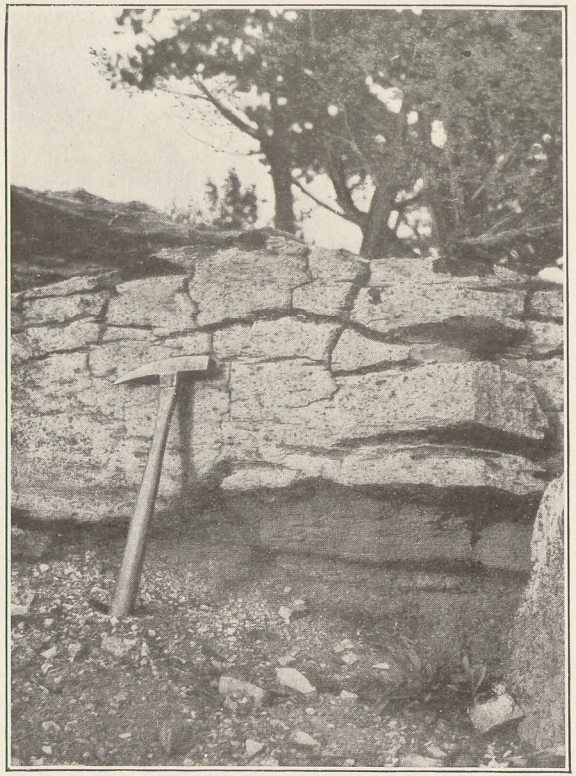
OIL SHALE.

PHYSICAL CHARACTER.

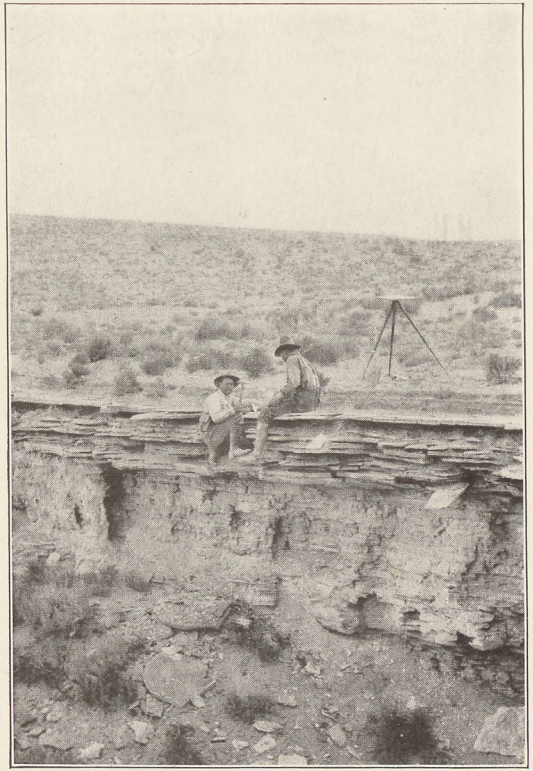
The term "oil shale" as used in this report is applied to a shale that contains materials from which oil may be made by distillation as distinct from a shale that contains oil which can be extracted with a solvent or which may be obtained by penetrating the bed with a drill. Thus the tough, dark shales of the Green River formation of Colorado, Utah, and Wyoming and the Tertiary shales of Nevada (Green River?) are considered true oil shales, whereas the locally impregnated shale of the Monterey group of southern California is not, inasmuch as the oil it contains may be almost entirely removed by treatment with a solvent such as chloroform.

The oil shales of the Rocky Mountain region present a large variety of types. Even in a single locality there may be several distinct shales, each of which is sufficiently rich in oil-forming materials to be of commercial interest. The phosphatic oil shales of the Phosphoria formation, for example, are very dark brown or black, but the richer shales of the Green River formation range in color from jet-black like coal to light brown, and the rich Tertiary oil shales of the Elko district in Nevada and the Tertiary shales of southwestern Montana range from brown to light yellow. Most of the richer oil shales have a waxy or velvet-like luster, but some of the rich shales of Elko and southwestern Montana are dull and stony. Most shales are thinly laminated, but in some of them the laminations are not evident (see Pl. IV, *A*) until they have been heated and the oil driven off. Many of the shales that weather to paper-thin laminae may be found apparently massive and homogeneous in unweathered condition. Oil shale is almost always very fine grained, free from grit, and slightly calcareous. In weathered outcrops most of the richer shales are bluish, probably owing to the presence over the dark surface of the unweathered material of a thin film of white calcite or aragonite.

Some of the rich oil shales consist of alternating light and dark bands which are compacted into an apparently homogeneous mass, and in some places these bands are contorted and broken and recemented,

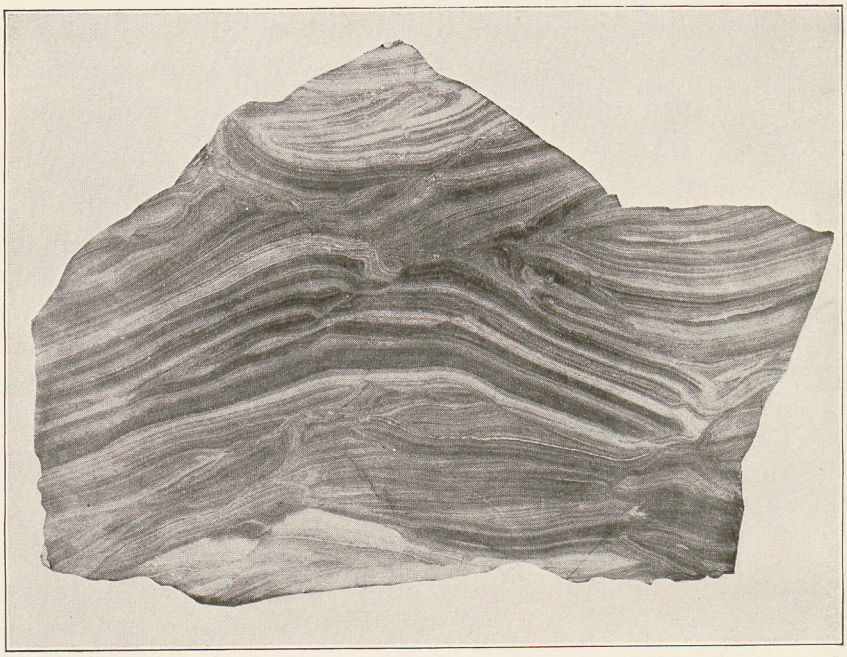


A. CHARACTERISTIC WEATHERING OF RICH MASSIVE OIL SHALE.

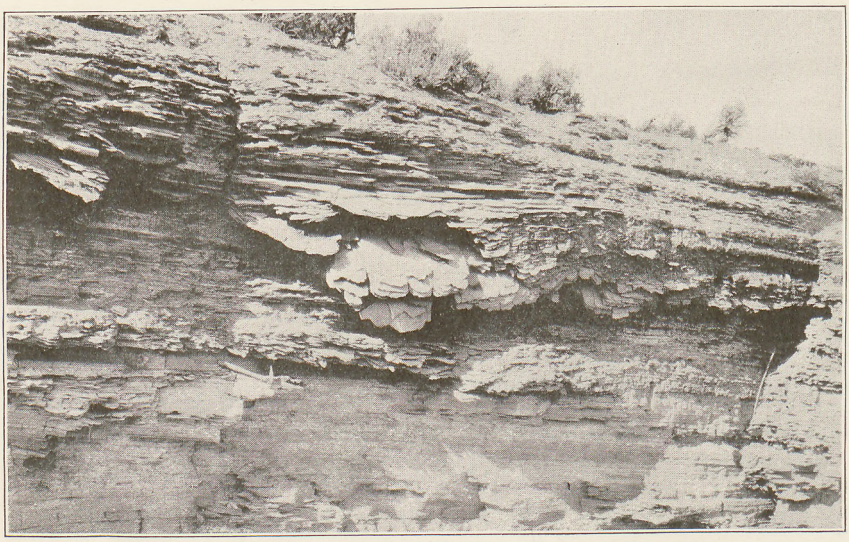


B. SAMPLING BED OF OIL SHALE SOUTH OF GREEN RIVER, WYO.

Shows characteristic weathering of bed containing alternating rich and poor seams. The richer seams are more resistant.



A. CONTORTED "VELVET" OIL SHALE FOUND NEAR GRAND VALLEY, COLO.



B. THIN-BEDDED OIL SHALE, SHOWING FLEXIBILITY.

suggesting that the material had been subjected to movement and crushing after it was partly solidified. (See Pl. V, *A*.) The rich oil shales of the Green River formation are very tough, rubbery, and even flexible (Pl. V, *B*) in thin-bedded specimens. Almost any oil shale is hard to cut or break with an ax or pick. When freshly broken oil shale gives off a peculiar odor like petroleum, although the rock contains but little oil as such. Thin slivers of an oil shale that yields more than 15 gallons of oil to the ton will burn with a sooty flame when ignited with a match.

The bituminous content of the oil shales renders them less susceptible to attack by the elements than most of the sedimentary rocks with which they are interstratified. Their toughness and hardness hinder disintegration, so that in many weathered hillsides the rich beds stand out as prominent ledges and the slopes below may be strewn with flags of oil shale. (See Pl. IV, *B*.)

Oil shale is heavier than coal and has a very high ash content (about 60 per cent as compared with 10 per cent in coal), and in general the shales that are lightest in specific gravity are the best producers of oil.

Relation of the specific gravity and ash content of oil shale of the Green River formation of Colorado and Wyoming to the amount of oil that can be distilled from the shale.

Locality.	Yield of oil (gallons to the ton).	Specific gravity.	Ash content (per cent).
Sec. 14, T. 1 S., R. 97 W., Colo.	15	2.21	60.5
Roan Creek, Colo.	27	2.11	40.6
Sec. 27, T. 7 S., R. 100 W., Colo.	44	1.69	51.3
Fossil, Wyo.	50	1.89	50.4
Sec. 15, T. 7 S., R. 96 W., Colo.	62	1.69	49.7
Parachute Creek, Colo.	75	1.59	56.3
Watson, Utah	90	1.39	39.9

Under the microscope the rich oil shale of the Green River formation consists of minute laminae of light-colored, partly crystalline material, probably largely mineral, interbedded with dark bands of noncrystalline material, probably largely organic.

In any one locality there may be several distinct types of oil-yielding shale—black massive shales with conchoidal fracture that resemble cannel coal; thinly but irregularly laminated "velvet" oil shales (Pl. V, *A*); thin-bedded dark shales known locally as paper shales; very thinly bedded light-brown shales which in weathered outcrop present peculiar curly forms; and massive bedded shales of various hues of brown. Each of these shales presents peculiar problems for the miner and for the retort engineer, and each may require slightly different handling to give the best results.

CHEMICAL CHARACTER.

No complete analyses of American oil shale have been made, but "ultimate" analyses such as are made of coal show the following results. In these analyses the inorganic materials of the shale appear largely as ash.

Analyses of samples of shale from the Green River formation in Colorado and Utah and the Tertiary shale (Green River?) of Nevada.

[Made at the Washington laboratory of the Bureau of Mines; J. D. Davis, chemist in charge.]

Sample No.	Location. State.	Sec.	T.	R.	Form of analysis.[a]	Proximate. Moisture.	Volatile matter.	Fixed carbon.	Ash.	Ultimate. Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Heating value (British thermal units).
4	Utah.....	(b)	.....	.....	A	1.05	33.55	(c)	65.43	0.27	1.80	13.37	0.39	18.74	2,266
					C	.....	33.91	(c)	66.12	.28	1.70	13.51	.39	18.00	2,290
6	Nevada...	(d)	.....	.....	A	1.05	45.04	(c)	45.73	1.07	5.19	36.76	.39	10.86	7,714
					C	.....	45.52	(c)	46.21	1.08	5.13	37.15	.39	10.04	7,796
27	Colorado..	11	1 N.	97 W.	A	3.18	19.55	(c)	79.00	1.08	1.75	8.34	.46	9.37	1,157
					C	.....	20.19	(c)	81.59	1.12	1.44	8.61	.48	6.76	1,195
32	...do.....	11	1N.	97 W.	A	.45	37.90	(c)	62.65	.55	2.76	22.48	.54	11.02	4,012
					C	.....	38.07	(c)	62.93	55	2.72	22.58	.55	10.67	4,030
51	...do.....	6	6 S.	94 W.	A	.43	39.85	(c)	59.95	.30	2.24	18.87	.46	18.18	3,055
					C	.....	40.02	(c)	60.21	.30	2.20	18.95	.46	17.88	3,068
57	...do.....	1	7 S.	98 W.	A	.85	51.60	(c)	46.23	.95	4.32	36.40	1.22	10.88	6,976
					C	.....	52.04	(c)	46.63	.96	4.26	36.71	1.23	10.21	7,036

[a] Analysis A represents the composition of the sample as it comes from the ground. Analysis C represents the theoretical condition of the shale after all the moisture has been eliminated.

[b] Soldier Summit, Utah.

[c] The conditions of heating in the volatile matter determination are different from those in the ash determination, and owing to different reactions the quantity of inorganic residue is not the same in both. As a result, the value of the fixed carbon is for some examples negative.

[d] Elko, Nev.

Both the nitrogen and the sulphur in oil shale are to play important parts in the commercial development of the oil-shale industry—the nitrogen because it may be converted into products worth recovering, and the sulphur because of its tendency to enter compounds which, if allowed to remain in the oil, will be a serious detriment to the oil. In the oil shales of the Green River formation of Colorado, Utah, and Wyoming the percentage of nitrogen is greatest in the shales that will yield the most oil when distilled and is least in the leanest shales, and the relation is so remarkably constant that it is possible by the use of the following formula to estimate fairly accurately the percentage of nitrogen in any oil shale of that age from the figure representing the shale's richness in oil:

$$\text{Nitrogen (per cent)} = 0.102 + (0.0133 \times \text{gallons of oil per ton of shale}).$$

The diagram in figure 1 presents the data from which the formula was derived. The percentage of nitrogen in each of more than 100 samples of oil shale is plotted as ordinates and the number of gallons of oil that can be distilled from a ton of the same samples is plotted as abscissas. The line represents the average relation of these two factors and is expressed by the formula given above.

Because of the close relation shown to exist between the oil and nitrogen it seems fair to conclude that the nitrogen in the shale is also largely organic rather than a part of the mineral matter. The sulphur in the shale (see table on pp. 69-72), on the contrary, appears to bear no relation to the oil and therefore perhaps is derived in large part from the inorganic portion of the shale. If this is the case, then it should be less difficult to prevent the sulphur entering the shale oil in the form of damaging compounds.

The black shales of the Phosphoria formation in some places in the Rocky Mountain region contain small percentages of phosphate, but only a few of the many samples tested by the United States Geological Survey have proved sufficiently rich in oil or phosphate or even

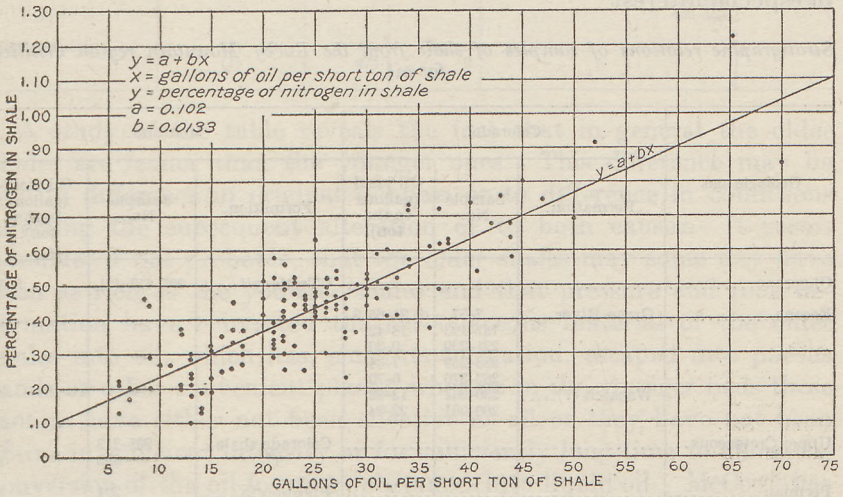


FIGURE 1.—Diagram showing relation of nitrogen in oil shale of Green River formation to yield of oil from the same shale.

in the two combined to be of especial interest. The only shales of this age that gave oil in sufficiently large quantity to be of interest came from the Dillon-Dell region in southwestern Montana. A discussion of the extent, richness, and value of these shales is given in the section on Montana oil shales.

Potash is common in oil shale, as it is in many other rocks, but in none of the samples so far examined has there been found an appreciable amount of soluble potash, the form required to make it of value as a fertilizer.

Reports of oil shale containing gold, platinum, zinc, lead, silver, antimony, and other metals have been circulated, but as yet no oil shales carrying appreciable amounts of any of these metals have been brought to the attention of the Geological Survey. Such shales may be found, but it is almost certain that they will be very slight in extent and therefore practically valueless.

DISTRIBUTION.

GENERAL GEOLOGY.

FORMATIONS CONTAINING OIL SHALE.

In the Rocky Mountain region carbonaceous materials from which oil may be distilled are to be found among the rocks of nearly every geologic period from the Devonian to the Quaternary, but by far the richest and most extensive deposits are those belonging to the Green River formation, of Eocene age. It should be pointed out that up to the present time the Survey's study has been confined largely to these richer shales and that more careful search may reveal shales of considerable value belonging to formations that do not now appear to be of especial interest

Stratigraphic relations of samples of shale from the Rocky Mountain region distilled for oil.

Geologic age.	Colorado.			Montana.		
	Formation.	Sample No.	Oil yield (gallons to the ton).	Formation.	Sample No.	Oil yield (gallons to the ton).
Oligocene				"Tertiary"	205, 412–421	0–36
Eocene	Green River	7–57	0.31–65.3			
		187–193	18–42			
		221–229	9–30			
		233–259	7–34			
		262–376	6–70			
	Wasatch (?)	230–232	12–22			
		260–261	22–24			
Upper Cretaceous				Colorado shale	208–212	0–2
				(?)	392	12
Permian				Phosphoria	204	24
					206	9
					207	3
					393–411	Trace–21
					517	6
					524A	3
Pennsylvanian and Mississippian.				Quadrant	377–386	0–19
Devonian				Threeforks	387–391	0–10

Geologic age.	Nevada.			Idaho.		
	Formation.	Sample No.	Oil yield (gallons to the ton).	Formation.	Sample No.	Oil yield (gallons to the ton).
Quaternary				(?)	463	20
Eocene	Green River (?)	6, 132	50–86.8			
		480–485	11–70			
Upper Cretaceous				Frontier	459–462	2–38
Permian				Phosphoria	196	6
					426–429	3
					432–449J	0–Trace

Stratigraphic relations of samples of shale from the Rocky Mountain region distilled for oil—Continued.

Geologic age.	Utah.			Wyoming.		
	Formation.	Sample No.	Oil yield (gallons to the ton).	Formation.	Sample No.	Oil yield (gallons to the ton).
Eocene	Green River	5	11.9	Green River	5	29.4
		58–91	1–90		92–131	3–50
		133–186	2.5–50		467–472	4–37
Upper Cretaceous	Colorado (cannel coal).	218	70	Thermopolis	219	0
				Mowry	220	1
				(?)	473	5
				Bear River	464–466	1–11
Permian				Phosphoria	422–425	0
					430–431	Trace.
					450–458	0
Mississippian	(?)	474	Trace.			
	(?)	475	0			

A study of the table reveals the fact that in general the older shales are leaner than the younger ones. This difference may be due to difference in original richness or to difference in conditions affecting the subsequent alteration or to both causes. It seems possible, if not probable, that the older shales may some day have been as rich as the younger shales and that pressure and rock deformation have converted the carbonaceous material of the older shales into oil, which has, since its formation, escaped into porous sands or other convenient places, whereas in the younger beds these factors have either not been effective at all or they have not been active in sufficient intensity or for sufficiently long time to allow the conversion of the oil-forming substances into liquid oil. McCoy[6] has proved by experiments that liquid oil may be formed from oil shale which does not contain free oil, by the proper application of pressure, without the application of heat. In his experiments McCoy has submitted shale to conditions which it is probable are similar to the conditions to which shales may be subjected in nature. The effect of the heat applied in the commercial shale retort is in McCoy's experiments replaced by the combined agents pressure and rock flowage.

DEVONIAN.

Material from the Threeforks formation, which contains dark-colored shales, has been examined and tested at several places in west-central Montana. These shales are badly deformed, and any oil-forming substances they formerly contained must have been almost entirely transformed and the hydrocarbons expelled, for even

[6] McCoy, A. W., Notes on principles of oil accumulation: Jour. Geology, vol. 27, No. 4, pp. 252–262, 1919.

the best sample showed only 2 gallons of oil to the ton. A sample of coal from the same formation upon distillation gave 10 gallons to the ton.

MISSISSIPPIAN.

Dark shales of Mississippian age were sampled and tested at two localities in northeastern Utah, but neither sample was found to give more than a trace of oil.

PENNSYLVANIAN AND MISSISSIPPIAN.

The Quadrant formation in west-central Montana includes dark shales at several localities. Samples were collected and tested from several beds near Adel post office, in Meagher County, where the best sample showed 19 gallons to the ton and most of the samples gave only 2 to 7 gallons. At this point the beds are badly folded, so that the result is not at all surprising. Samples from three other localities in the same State gave no oil when distilled.

PERMIAN.

The Phosphoria formation, of Permian age, was examined in considerable detail in Montana, Idaho, and Wyoming by D. D. Condit,[7] and 72 samples from this formation have been distilled. The association of the oil shale with beds carrying appreciable percentages of phosphate made it appear that perhaps the two might be profitably worked together, but in most places where the shale is rich in oil-forming substances neither the associated shales nor the oil-yielding shales themselves are sufficiently rich in phosphorus to make them particularly attractive. In general the shales of this formation are richest in the southwestern Montana region and are progressively leaner toward the south; the samples from the area in southeastern Idaho where the beds are associated with high-grade phosphate rock yield little more than a trace of oil. The oil shales of the Phosphoria formation are so nearly black that they have been mistaken for coal by prospectors at many places along their outcrop. The beds practically everywhere dip steeply and in many places are extensively faulted.

TRIASSIC, JURASSIC, AND LOWER CRETACEOUS.

Up to the present time no shale from the Triassic, Jurassic, and Lower Cretaceous beds has attracted the attention of those who have been looking for oil shale, and therefore no samples have been tested.

UPPER CRETACEOUS.

Shale and coaly material from beds of Upper Cretaceous age have been examined, but the results have not been especially encouraging. Samples of the dark-colored Mowry shale, the Thermopolis shale of

[7] Op. cit.

the Big Horn Basin, Wyo., and the Colorado shales of Montana gave very little oil when distilled. Coal and associated carbonaceous shale from the Bear River formation in western Wyoming and from the Frontier formation in eastern Idaho gave more encouraging results, but it is probable that the beds from which the good tests were obtained are neither thick nor extensive. In southern Utah there is, near the base of the Upper Cretaceous beds at one locality, a bed of cannel coal. As a fresh sample of this coal was not available it was necessary to use in the test a sample that had been inclosed in a glass jar for about 10 years, and the results are therefore probably not accurate. However, this coal gave oil at the rate of 70 gallons to the ton and therefore is of considerable interest, inasmuch as its percentage of nitrogen is also relatively high. No information is available as to the area underlain by this bed, although Richardson, who collected the sample in 1907, expressed the belief[8] that in all probability the bed was only local in extent.

EOCENE.

Up to the present time shale yielding oil on distillation has been studied in the Wasatch (?) and Green River formations of the Eocene series. In northwestern Colorado thin-bedded, papery shales occurring below red and green clay shales are tentatively referred to the Wasatch formation, and tests on beds of this zone gave oil at the rate of 12 to 24 gallons to the ton. The extent of these beds is not known, but because of the general lenticular nature of beds of the Wasatch formation it is probable that they are neither continuous nor of regular thickness. However, inasmuch as the samples were taken from two localities rather widely separated it is possible that careful study might locate beds of sufficient thickness and extent to make them of commercial importance.

By far the most extensive and rich oil shales of the United States and perhaps of the world belong to the Green River formation of Colorado, Utah, and Wyoming and the Tertiary shales (Green River?) of Nevada. The rich shales of Colorado are the exact equivalent of those in northeastern Utah, and the rich oil shales of southwestern Wyoming are of approximately the same age, but those near Elko, Nev., may be slightly younger.

The Green River shales of the Uinta Basin in Colorado and Utah and of the Green River Basin of southwestern Wyoming and the shales of the Elko Basin of Nevada contain fossils in abundance, both megascopic and microscopic. The writer has made several

[8] Richardson, G. B., The Harmony, Colob, and Kanab coal fields, southern Utah: U. S. Geol. Survey Bull. 341, p. 394, 1909.

collections, which included shells, insects, leaves, fish, and bird bones. Scudder and others have made collections from these same beds at different times, and a more or less complete list of the species so far collected from the Green River formation is included in this report (pp. 23–31):

Of the fossil insects, a complete list of which follows, Dr. T. D. A. Cockerell says:

> The Mesozoic insects are very modern in appearance when compared with those of the Paleozoic; but it is not until we come to the Eocene that we find an extensive fauna of essentially modern type, including a number of genera still living. From the Eocene rocks, generally classed as of Green River age, in Colorado, Wyoming, and Utah no less than 279 species of insects have been described. This is an extensive series but is only a beginning. Hundreds of additional specimens have been collected, mainly by Scudder and Winchester, and from their reports it is certain that many thousands could readily be obtained. New collections will always contain only a small percentage of really fine specimens, but where the materials are so abundant many beautiful things may be confidently expected. The records of Eocene insects outside of the Rocky Mountains are very few. Eleven, nearly all beetles, are recorded from Greenland; one beetle from Grinnell Land; seven species from Italy; four from England—23 species altogether. An odonatid larva (*Austrolestidion duaringae* Tillyard) from Australia is perhaps Eocene, possibly Cretaceous. Thus, were it not for the Rocky Mountain Eocene, we should be without a satisfactory Tertiary insect fauna lower than the Oligocene, the time of the Baltic amber.
>
> The time has not yet come for a detailed summary of the Rocky Mountain Eocene insect fauna, but a few points may be noted. We have as yet no really large insects (the largest are dragon flies). Beetles are very numerous, with 32 species. Orthoptera are represented by five species, Odonata by seven. No Lepidoptera have been found. Diptera are numerous and include some of the higher families. Several dipterous genera are identical with those now living. The Hymenoptera are mostly parasitic, including very characteristic Ichneumonidae and Braconidae. No bees have been found. The most striking feature is the abundance of Fulgoridae (26 species), many of them broad-winged and mothlike, elegantly spotted or banded. These fulgorids have a tropical facies and closely resemble those now living in the Indo-Malay region. In the Rocky Mountain Eocene landscape gay and pretty Fulgoridae must have flitted about in abundance, looking like moths. If there were also genuine moths and butterflies, they must have been rather scarce, or some would have been found among the hundreds of specimens examined. A really satisfactory Eocene ant is still lacking.
>
> From the typical Green River beds of Wyoming about 140 species of insects are known. Although the Colorado-Utah series is assigned to the Green River it can hardly be contemporaneous with the Wyoming rocks, as the insects of the latter are essentially distinct. Only 15 species are at present recognized as common to the Wyoming Green River and the Colorado-Utah series, and it is not certain but that closer scrutiny and better materials will rather decrease than increase these numbers. Of course it is possible that the differences may be due in part to different ecologic conditions, though there is no distinct evidence pointing in this direction.

The following is a list of insects which have been identified from the Green River formation, with the locality or localities from which each species has been collected:

Insects (in the broad sense) and other arthropods of the Green River formation.

[G., Green River, Wyo.; R. M., Roan Mountain, Colo.; C. B., Cathedral Bluffs, Colo.; W., White River near Colorado boundary; U., Utah.]

Diplopoda:
Julidae:
Julus telluster Scudder. G.

Arachnida:
Aranea columbiae Scudder. G. (Egg cocoon, doubtless distinct from the original A. columbiae from Quesnel.)
Ixodidae:
Ixodes tertiarius Scudder. G.

Insecta:
Orthoptera:
Acridiidae:
Tyrbula multispinosa Scudder. G. (The fossil from Florissantia supposed by Scudder to be this species is distinct; see Cockerell, T. D. A., Entomologist, January, 1914, p. 34.)
Blattidae:
Paralatindia saussurei Scudder. G.
Gryllidae:
Pronemobius induratus Scudder. G.
Pronemobius tertiarius Scudder. G.
Pronemobius smithii Scudder. G.
Pronemobius ornatipes Cockerell. G.
Odonata:
Zygoptera:
Dysagrion fredericii Scudder. G.
Dysagrion lakesii Scudder. G.
Dysagrion packardii Scudder. G.
Podagrion abortivum Scudder. G.
Eocalopteryx atavine Cockerell. G.
Protamphipteryx basalis Cockerell. G.
Eopodagrion scudderi Cockerell. G.
Anisoptera:
Stenogomphus carletoni Scudder. G.
Stenogomphus scudderi Cockerell. G.
Psocina:
Psocidae:
Paropsocus disjunctus Scudder. G.
Trichoptera:
Hydropsyche operta Scudder. G.
Indusia calculosa Scudder. Horse Creek, Wyo. (Caddis case.) (?G.)
Limnephilus eocenicus Cockerell. R. M.
Hydrophila philcos Cockerell. C. B.
Coleoptera (families arranged alphabetically):
Anthribidae:
Tropideres remotus Scudder. G.
Hormiscus partitus Scudder. G.
Cratoparis elusus Scudder. G.
Cratoparis repertus Scudder. G.
Brachytarsus pristinus Scudder. G.
Choragus fictilis Scudder. G.

Insecta—Continued.
Coleoptera—Continued.
Bruchidae:
Bruchus anilis Scudder. W.
Byrrihidae:
Nosodendron tritavum Scudder. G.
Calandridae:
Sciabregma rugosa Scudder. R. M.
Sciabregma tenuicornis Cockerell.
Calandrites defersus Scudder. R. M.; C. B.
Calandrites cineratius Scudder. R. M.; C. B.
Cossonus rutus Scudder. R. M.
Carabidae:
Neothanes testeus Scudder. G.
Bembidium exoletum Scudder. W.
Carabites exanimus Scudder. U.
Carabites eocenicus Cockerell. W.
Carabites kincaidi Cockerell (larva). G.
Platynus senex Scudder. G.
Platynus caesus Scudder. G.
Galerita marshii Scudder. G.
Harpalus veterum Cockerell. R. M.
Lebia protospiloptera Cockerell.
Chrysomelidae:
Lema? pervetusta Cockerell. R. M.
Cryptocephalus vetustus Scudder. G.
Cicindelidae?:
Cicindelopsis sophilus Cockerell. W.
Cryptophagidae:
Antherophagus priscus Scudder. G.
Cucujidae:
Parandrita vestita Scudder. G.
Curculionidae:
Sitona fodinerum Scudder. G.
Sitona paginerum Scudder. R. M.; G.
Limalophus compositus Scudder. G.; U.
Limalophus contractus Scudder. G.
Coniatus refractus Scudder. U.
Apion evestigatum Scudder. R. M.
Lepyrus? evictus Scudder. G.
Listronotus muratus Scudder. G.
Pachylobius deleticius Scudder. U.
Pachylobius compressus Scudder. R. M.; G.
Pachylobius depraedatus Scudder. R. M.
Hylobius provectus Scudder. G.
Hylobius packardii Scudder. G.
Procas vinculatris Scudder. R. M.; U.
Anthonomus soporus Scudder. G.; W.; R. M.
Anthonomus revictus Scudder. G.
Gymnetron lecontei Scudder. G.
Rhynomatus tabescens Scudder. R. M.
Cryptorhynchus durus Scudder. R. M.
Cryptorhynchus annosus Scudder. R. M.; W.
Ceuthorhynchus degravatus Scudder. R. M.

Insecta—Continued.
Coleoptera—Continued.
Curculionidae—Continued.
Aulobaris anicilla Scudder. R. M.
Aulobaris circumscripta Scudder. R. M.; U.
Aulobaris comminuta Scudder. W.; U.
Centrinus diruptus Scudder. G.
Dytiscidae:
Laccophilus sp. Scudder (fragment of leg only). U.
Elateridae:
Epiphanis deletus Scudder. U.
Corymbites velatus Scudder. G.
Oxygonus mortuus Scudder. U.
Adocetus luprestoides Scudder (22 millimeters long). Bluffs by Twin Creek, Fossil, Wyo.
Erotylidae:
Mycotretus binotatus Scudder. G.
Hydrophilidae:
Hydrochus relictus Scudder. G.
Tropisternus sculptilis Scudder. G.
Tropisternus saxialis Scudder. G.
Berosus sexstriatus Scudder. G.
Berosus tenuis Scudder. G.
Laccolius elongatus Scudder. G.
Philhydrus primaevus Scudder. G.
Hydrobius decineratus Scudder. G.
Hydrobius confixus Scudder. G.
Nibidulidae:
Phenolia incapax Scudder. G.
Otiorhynchidae:
Epicaerus exanimis (Scudder). G.; R. M.; W.; U.
Epicaerus saxatilis (Scudder). G.; R. M.
Epicaerus effossus (Scudder). G.; R. M.; U.
Ophryastes compactus Scudder. G.
Ophryastes petrarum Scudder. R. M.
Ophryastes grandis Scudder. R. M.
Ophryastites dipressus Scudder. W.
Ophryastites disperditus Scudder. R. M.
Exomias obdurefactus Scudder. R. M.
Phyxalis dilapsus Scudder. G.
Phyxalis excissus Scudder. R. M.
Phyxalis evigoratus Scudder. W.; U.; R. M.
Phyxalis eradicatus Scudder. R. M.; U.
Otiorhynchus perditus Scudder. G.
Otiorhynchus sutterachus Scudder. R. M.
Otiorhynchus tumbae Scudder (dubius Scudder). G.
Otiorhynchus flaccus Scudder. R. M.
Otiorhynthites tysoni Scudder. R. M.; G.(?)
Otiorhynchites fossilis Scudder. Fossil, Wyo.
Otiorhynchites commutatus Scudder. R. M.
Neoptocus? sp. W.; R. M.
Tanymecus secularum Scudder. G.
Entimus primordialis Scudder. W.

Insecta—Continued.
Coleoptera—Continued.
Otiorhynchidae—Continued.
Syntomostylus rudis Scudder. R. M.; W.
Syntomostylus? fortis Cockerell. G.
Artipus? receptus Scudder. U.
Phyllobius antecessor Scudder. R. M.
Phyllobius carcerartus Scudder. W.; U.
Phyllobius avus Scudder. U.; G.
Scythropus subterraneus Scudder. G.; U.; R. M.
Scythropus somniculosus Scudder. R. M.
Scythropus? abacus Scudder. W.
Endiagogus terrosus Scudder. R. M.; W.
Ptinidae:
Sitodrepa defuncta Scudder. G.
Anolium? ovate Scudder. G.
Anolium? deceptum Scudder. G.
Anolium lignitum Scudder. G.
Rhynchitidae:
Eugnamptus grandaevus (Scudder). G.
Eugnamptus decemsatus Scudder. G.
Paltorhynchus? lisulcatus Scudder. R. M.
Teretrum quiescitum Scudder. G.
Steganus barrandei Scudder. R. M.
Scarabaeidae:
Aegialia rupta Scudder. G.
Melolonthites avus Cockerell.
Scolytidae:
Dryocoetes impressus (Scudder). G.
Dryocoetes carbonarius Scudder. G.
Polygraphus wortheni Scudder. R. M.
Staphylinidae:
Homalota recisa Scudder.
Gyrophaena saxicola Scudder. W.
Leistotrophus patriarchicus Scudder. W.
Lathrolium abcessum Scudder. G.
Bledius faecorum Scudder. G.
Bledius adamus Scudder. G.
Oxytelus pristinus Scudder. W.
Staphylinites obsoletum Scudder. G.
Physapodes:
Melanothrips extincta Scudder. W.
Lithadothrips vetusta Scudder. U.
Palaeothrips fossilis Scudder. U.
Homoptera:
Aphididae:
Lithaphis diruta Scudder (type from Florissant). G. (?)
Cercopidae:
Cercopites umbratilis Scudder. G.
Cercopites calliscens Scudder. G.
Cercopis astricta Scudder. G.
Cercopis (2 labs.) cephralinus Cockerell. C. B.
Palecphora patefacta Scudder. G.

Insecta—Continued.
Homoptera—Continued.
Fulgoridae:
Aphana atava Scudder. W.
Aphana rotundipennis Scudder.
Lystra? richardsoni Scudder. G.
Lystra? leei Scudder. G.
Fulgora granulosa Scudder. G.
Fulgora populata Scudder. G.
Cixius? besperidum Scudder. G.
Oliarus? lutensis Scudder. G.
Diaphlegma obdormitum Scudder. G.
Oliarites terrentula (Scudder). G.
Delphax senilis Scudder. W.; possibly U.
Delphax veterum Cockerell. C. B.
Hammapteryx reticulata Scudder. G.
Hammapteryx? lepidoides Cockerell. C. B.
Hammapteryx? ceryniiformis Cockerell. C. B.
Lithopsis fimbriata Scudder. G.
Lithopsis elongata Scudder. G.
Lithopsis delicata Cockerell. C. B.
Lithopsis simillina Cockerell. R. M.
Ficarasites stigmaticum Scudder. G.
Eofulgorella bradburyi Cockerell. Near Rifle, Colo.
Detyopsis scudderi Cockerell. R. M.
Detyopsis packardi Cockerell. R. M.
Protoliarus humatus Cockerell. C. B.
Scoparidea nebulosa Cockerell. R. M.
Dilaropis ornatus Cockerell. C. B.
Callospilopteron ocellatum Cockerell. G.
Jassidae:
Cicadula saxosa Scudder. G.
Acocephalus adae Scudder. G.
Coelidia wyomingensis Scudder. Twin Creek, Wyo.
Tettigonia priscomarginata Scudder. G.
Tettigonia priscovariegata Scudder. G.
Tettigonia obtecta Scudder. W.
Cicadella (broad sense) scudderi Cockerell. R. M.
Erythroneura eocenica Cockerell. R. M.
Bythoscopus lapidescens Scudder. W.
Thamnotettix mutilata Scudder. G.
Thamnotettix gannetti Scudder. G.
Heteroptera:
Acanthiidae:
Lyctocoris terreus (Scudder). G.
Corcidae:
Corizus guttatus (Scudder). G.
Jadera? interita. Cockerell. Rifle, Colo.
Galgulidae:
Necygonus rotundatus Scudder. G.
Hydrobatidae:
Telmatrechus parallelus. Scudder. Twin Creek, Wyo.

Insecta—Continued.
Heteroptera—Continued.
Lygacidae:
Cholula triguttata Scudder. G.
Pachymerus petrensis Scudder. U.
Pentatomidae:
Stenopelta punctulata (Scudder). G.
Procydnus mamillanus (Scudder). G. (also said to occur at Florissant).
Necrocydnus gosiutensis Scudder. G.
Cyrtomenus concinnus Scudder. G.
Cydnopsis handlirschi Cockerell. Rifle, Colo.
Dinidorites margiformis Cockerell.
Diptera:
Anthomyiidae:
Anthomyia (broad sense) winchesteri Cockerell. C. B.
Asilidae:
Stenocinclis anomala Scudder. G.
Asilus palaeolestes Cockerell. W.
Asilopsis fusculus Cockerell. W.
Bibionidae:
Plecia pealei Scudder. Twin Creek, Wyo.
Plecia dejecta Scudder. G.
Plecia winchesteri Cockerell. C. B.
Plecia woodruffi Cockerell. Evacuation Creek, Utah.
Blepharoceridae:
Philorites johannseni Cockerell. Rifle, Colo.
Philorites pallescens Cockerell. C. B.
Cecidomyiidae:
Lasioptera recessa Scudder. W.
Lithomyza condita Scudder. W.
Chironomidae:
Chironomus septus Scudder. G.
Chironomus depletus Scudder. W.
Chironomus patens Scudder. W.
Conopidae:
Poliomyia recta Scudder. G.
Culicidae:
Culex damnatorum Scudder. G.
Culex proavitus Scudder. U.
Culex winchesteri Cockerell. C. B.
Corethra exita Scudder. W.
Cyrtidae:
Acrocera hirsuta Scudder. U.
Dolichopodidae:
Dolichopus sp. Scudder. G.
Empididae:
Rhamphomyia enana Cockerell.
Protoedalea brachystoma Cockerell. C. B.
Helomyzidae:
Heteromyza detecta Scudder. W.
Mycetophilidae:
Sciara scopuli Scudder. G.
Mycetophila occultata Scudder. W.

Insecta—Continued.
Diptera—Continued.
Mycetophilidae—Continued.
Anatella tacita Scudder. G.
Rhymosia strangulata Scudder. G.
Gnoriste dentoni Scudder. U.
Boletina umbratica Scudder. G.
Boletina paludivaga Scudder. G.
Sackenia arcuata Scudder. W.
Sackenia gibbosa Cockerell. G.
Anaclinia sp. Scudder. G.
Sciophila hyattii Scudder. G.
Diadocidia? terricola Scudder. G.
Tetragoneura peritula Cockerell. Rifle, Colo.
Diomonus palaeospilus Cockerell. G.
Palaeoplatyura? eocenica Cockerell. C. B.
Oestridae:
Lithohypoderma ascarides (Scudder). W.; C. B.; U. (larva).
The following probably belong to this group:
"Musca" bibosa Scudder (larva). W.
"Musca" hydropica Scudder (larva). W.
"Musca" vinculata Scudder (larva). W.
Platypezidae:
Callomyia [=Callimyia] torporata Scudder. G.
Callomyia hypolitha Cockerell. Rifle, Colo.
Sciomyzidae:
Sciomyza manca Scudder. G.; W.
Sciomyza disjecta Scudder. G.
Stratiomyidae:
Lithophysa tumulta Scudder. G.
Nemotelus eocenicus Cockerell. W.
Asarcomyia cadaver Scudder. G.
Sargus vetus Cockerell. W.
Syrphidae:
Milesia? quadrata Scudder. G.
Eristalis lapideus Scudder. W.
Syrphus sp. Scudder. G.
Syrphus lithophidis Cockerell. C. B.
Chilosia ampla Scudder. G.
Psilota tabidosa Scudder. G.
Tachinidae:
"Tachina" sp. Scudder. G.
Muscoid, family uncertain; resembles Tachinilas.
Acanthomyites aldrichi Cockerell.
Therevidae:
Eothereva simplex Cockerell. R. M.
Tipulidae:
Dicranomyia stigmosa Scudder. U.; W.
Dicranomyia primitiva Scudder. U.; ?G.
Dicranomyia rostrata Scudder. U.
Dicranomyia rhodolitha Cockerell. G.
Spiladomyia simplex Scudder. W.
Pronophlebia rediviva Scudder. W.
Cyttaromyia fenestrata Scudder. U.; W.

Insecta—Continued.
Diptera—Continued.
Tipulidae—Continued.
Tipula spoliata Scudder. G.
Tipula sepulchri Scudder.
(T. tecta Scudder is probably Dicranomyia stigmosa, and T. decrepita Scudder is probably D. rostrata. See Scudder, 1894.)
Cylindrotome veterana Cockerell. R. M.
Gonomyia scudderi Cockerell. R. M.
Hymenoptera:
Braconidae:
Bracon laminarum Scudder. G.
Eobracon cladurus Cockerell. W.
Ichneumonidae:
Ichneumon petrinus Scudder. W.
Mesochorus cressori (Scudder). (Referred by Brues to Mesochorus.) G.
Rhyssa juvenis Scudder. G.
Pimpla eocenica Cockerell. C. B.
Espimpla grandis Cockerell. G.
Glypta transversalis Scudder. G.
Eclytus lutatus Scudder. G.
Phygadeuon (broad sense) petrifactellus Cockerell. W.
Tilgidopsis haesitans Cockerell. W.
Chalcididae:
Decatoma antiqua Scudder. G.
Formicidae:
Liometopun pingue. Scudder. U.; G.
Lasius terreus Scudder. G.
Camponotus vetus Scudder. W.
Eoformica eocenica Cockerell.
Myrmicidae:
"Myrmica" sp. Scudder. G.
Sphegidae (broad sense):
Didineis? solidescens Scudder. G.
Tenthredinidae:
Taxonus nartoni Scudder. G.

F. H. Knowlton, who has in recent years studied the floras of the region, has assembled the following list of plant species for the formation. This list does not include the plants from Elko, Nev.

Acer lesquereuxii Knowlton, Uinta County, Wyo.
Acrostichum hesperium Newberry, Green River, Wyo. (Fish Cut).
Ailanthus longe-petiolata Lesquereux, Uinta County, Wyo.
Amygdalus gracilis Lesquereux, Uinta County, Wyo.
Andromeda delicatula Lesquereux, Uinta County, Wyo.
Antholithes improbus Lesquereux, Uinta County, Wyo.
Aralia wyomingensis Knowlton and Cockerell, Green River, Wyo.
Arundo reperta Lesquereux, Green River, Wyo
Brasenia? antiqua Newberry, Green River, Wyo.
Carpites viburni Lesquereux, Alkali station, Wyo.
Cissus parrottiaefolia Lesquereux, Green River, Wyo.
Cyperacites haydenii (Lesquereux) Knowlton, Uinta County, Wyo.
Cyperus chavannesi Heer, Green River, Wyo.
Equisetum wyomingense Lesquereux, Green River, Wyo.

Eucalyptus? americanus Lesquereux, Green River, Wyo.
Euonymus flexifolius Lesquereux, Uinta County, Wyo.
Ficus tenuinervis Lesquereux, Alkali station, Wyo.
Ficus ungeri Lesquereux, Green River, Wyo.
Ficus wyomingiana Lesquereux, Green River station, Wyo.
Flabellaria florissanti Lesquereux, Uinta County, Wyo.
Geonomites haydenii (Newberry) Knowlton, Green River, Wyo.
Ilex? affinis Lesquereux, Green River station, Wyo.; Carr Creek, Garfield County, Colo.
Ilex maculata Lesquereux, Alkali station, Wyo.
Ilex vyomingiana Lesquereux, Green River, Wyo.
Juglans alkalina Lesquereux, Alkali station, Wyo.
Juglans crossii Knowlton, Green River, Wyo.
Juglans occidentalis Newberry, Green River, Wyo.
Juglans schimperi Lesquereux, Green River, Wyo.
Juncus sp. Lesquereux, Green River, Wyo.
Leguminosites alternans Lesquereux, mouth of White River, Wyo. (probably Utah).
Lomatia microphylla Lesquereux, mouth of White River (Utah?).
Lygodium dentoni Lesquereux, mouth of White River (Utah?).
Lygodium kaulfussii Heer, Green River, Wyo.; Little Duck Creek, Rio Blanco County, sec. 33, T. 4 S., R. 100 W., Colo.
Musophyllum complicatum Lesquereux, Green River, Wyo.
Myrica ludwigii Schimper, mouth of White River, Wyo. (Utah?); Camp Gulch, T. 6 S., R. 99 W., Colo.; Carr Creek, Garfield County, Colo.
Myrica salicina Unger, Green River, Wyo.
Myrica sp., apparently new, sec. 33, T. 4 S., R. 100 W., Colo.
Myrica sp., new, Little Duck Creek, Rio Blanco County, Colo.
Nordenskiöldia borealis Heer, Green River, Wyo.
Osmunda? sepulta (Newberry) Knowlton, Green River, Wyo.
Parthenocissus tertiaria (Lesquereux) Knowlton, Green River station, Wyo.
Phyllites fremonti Unger, Blacks Fork of Green River, Wyo.
Phyllites sapindiformis Lesquereux, Green River, Wyo.
Planera inaequilateralis (Lesquereux) Knowlton, Alkali station, 30 miles north of Green River, Wyo.
Quercus castaneopsis Lesquereux, Uinta County, Wyo.
Rhus lesquereuxii Knowlton and Cockerell, Green River, Wyo.
Rhus nigricans (Lesquereux) Knowlton, Green River, Wyo.; Smith's ranch, Greasewood Creek, Little Duck Creek, Rio Blanco County, Colo.; Camp Gulch, T. 6 S., R. 99 W., Colo.
Rhus variabilis (Newberry), Knowlton, Green River, Wyo.
Sabal powellii Newberry, Green River, Wyo.
Salix sp., apparently new, sec. 33, T. 4 S., R. 100 W., Colo.
Salix sp., Green River, Wyo.
Sapindus dentoni Lesquereux, mouth of White River, Utah.
Sapindus obtusifolius? Lesquereux, Camp Gulch, T. 6 S., R. 99 W., Colo.
Sphaerites myricae (Lesquereux) Meschinelli, Green River station, Wyo.
Zizyphus cinnamomoides (Lesquereux) Lesquereux, Green River, Wyo.
Zizyphus longifolia Newberry, Green River, Wyo.

Fossil fish have been collected in large numbers from the shale beds near Fossil, Wyo., and from several other localities, including Elko, Nev. Many of the specimens from the Wyoming localities are so

excellently preserved that they have been collected and sold as museum specimens and curios.

Fresh-water shells are common in some localities, especially in the vicinity of Soldier Summit, Utah, and Elko, Nev.

Bird bones were collected from the Green River beds near Ephraim, Utah, and bird feathers were found in shale associated with the rich oil shale near Grand Valley, Colo., but the collections were not sufficiently large to make it possible for the birds to be described.

In addition to the fossils that are visible to the naked eye the microscope reveals many organic remains, mostly vegetal (Pls. VI, VII), only a very few of which have been studied and many of which are as yet undescribed. Dr. C. A. Davis at the time of his death in 1916 was busily engaged in a study of these microorganisms, but since then no one has continued the study, so the few notes that he left constitute our knowledge of them. Several hundred thin sections of the oil shale of the Green River formation had been prepared by Dr. Davis, and a few of these had been studied and photographed.

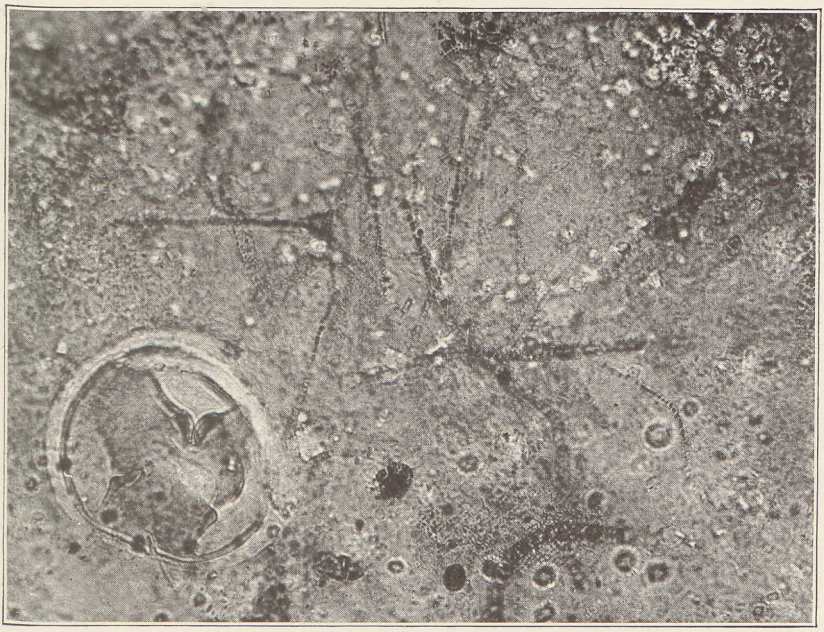
Flora of the oil shale of the Green River formation.

[Notes by C. A. Davis, March 30, 1915.]

Bacteria: *Crenothrix* and similar low filamentous types.
Myxophyceae: Blue-green algae.
Algae:
Protococcaceae: *Protococcus pediastrum.*
Conjugatae: *Spirogyra.*
Fungi: Saprophytic molds, etc.
Mosses: Spores probably from these plants.
Pteridophyta: Ferns; annuli from fern sporangia.
Spermatophyta:
Gymnospermae: Pinaceae: Pollen of *Picea* and *Pinus.*
Angiospermae: Pollen and fragments of cells, tissues, etc. Bark cells and residues, small pieces, poorly preserved. In addition there are abundant and well-preserved remains of good size and of frequent occurrence, which seem to be structureless so far as cellular structures are concerned. However, they have definite and pretty regular forms and, in *Dictyonophora*, definite areas which carry well-marked and characteristic patterns which seem like cells but which show no cell walls. These anomalous forms seem to have been the most abundant organisms in the waters in which the shales were laid down and are evidently vegetables of a low order of development. They are manifestly in place as they grew, for they do not show in pressed-down masses but were buried in natural positions, very slowly.

OLIGOCENE.

In western Montana, near Dillon, shales and coaly materials are present in rocks of possible Oligocene age, which occupy narrow, elongate basins between the mountains. The oil-yielding shale is light brown when fresh and weathers to a cocoa-color or nearly

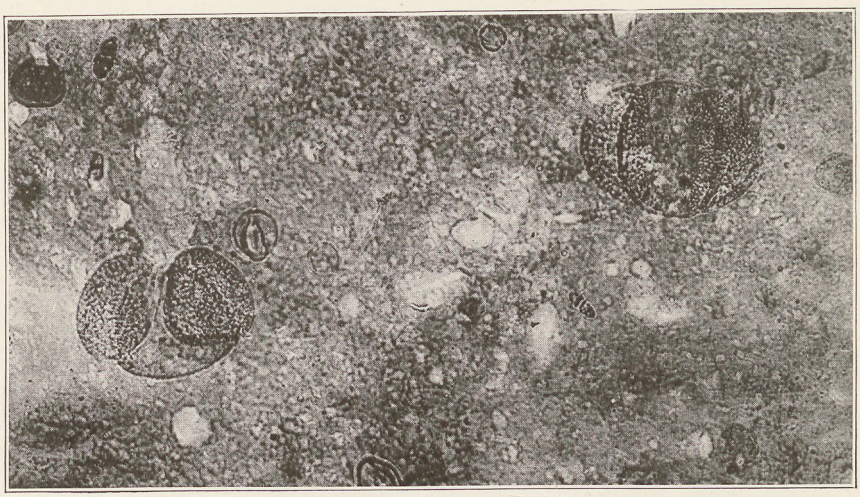


A.

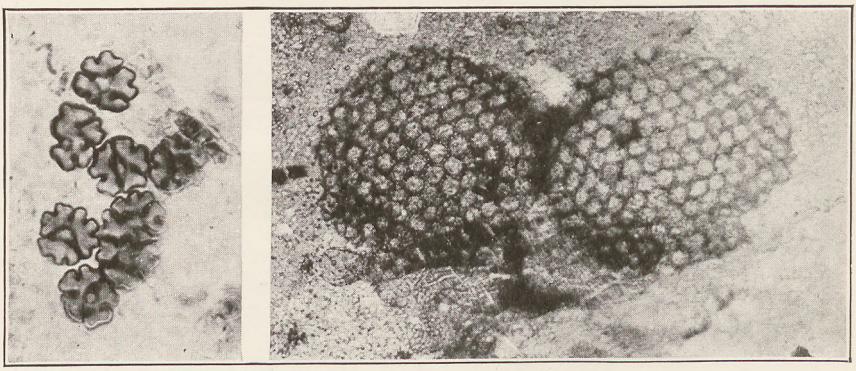
B.

FOSSIL VEGETABLE MATTER OF OIL SHALE OF GREEN RIVER FORMATION.

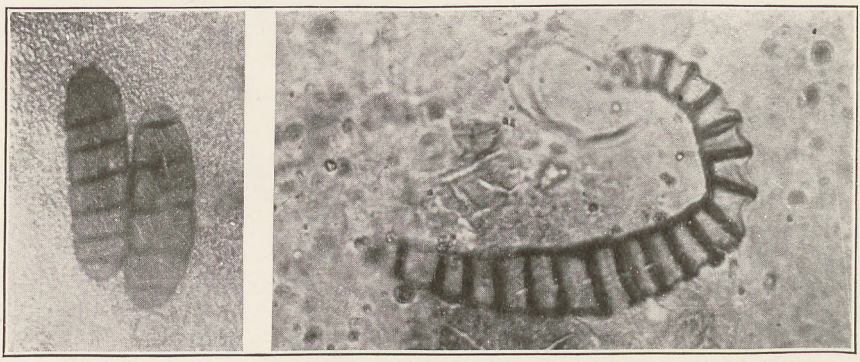
General views. From thin sections prepared by C. A. Davis. *A*, Magnified 410 diameters; *B*, magnified 215 diameters.



A



B



C

FOSSIL VEGETABLE MATTER OF OIL SHALE OF GREEN RIVER FORMATION.

Detailed views. From thin sections prepared by C. A. Davis. *A*, Pollen, magnified 245 diameters; *B*, left, yellow-green algæ, magnified 740 diameters; right, (?), magnified 120 diameters; *C*, left, spores, magnified 200 diameters; right, fern annulus, magnified 685 diameters.

white. In the process of weathering the shale breaks up into thin, flexible laminae or flakes resembling manila paper. This shale does not give an odor of petroleum when freshly broken. It is interbedded with coarse and fine sandstone, sandy shale, and lignite.

QUATERNARY.

About 4 miles south of Soda Springs, Idaho, black shale of probable Quaternary age is exposed in the bank of Bear River. This shale gave a fairly good yield of both oil and nitrogen, but little is known about its extent.

DETAILED INFORMATION BY STATES

COLORADO.

GENERAL FEATURES.

The Green River formation, which includes nearly all the oil shale in Colorado, is present in four different areas in the northwestern part of the State. (See Pl. VIII, in pocket.) Three of these areas, the Piceance Creek basin, Battlement Mesa, and Grand Mesa, are a part of the great Uinta Basin of northwestern Utah and northwestern Colorado, and the shale in these areas has been studied in considerable detail. The outcrop of the rich oil-shale zone and the richness of the several members are fairly well known.

These areas are all tributary to the Denver & Rio Grande Western Railroad, one of the main transcontinental railroads of the country, whose main line passes through Rifle, Grand Valley, De Beque, and Palisade and joins the narrow-gage Marshall Pass line of the same railroad at Grand Junction, 12 miles southwest of Palisade. The Marshall Pass line traverses the valley of Gunnison River along the south side of Grand Mesa.

Grand Junction, one of the largest towns on the western slope of the Rocky Mountains, is just outside the area shown on the map (Pl. VIII) and is in the center of a very rich farming and fruit-raising country. De Beque and Grand Valley, at the mouths of Roan and Parachute creeks, respectively, are small but prosperous towns and with the commercial development of the oil shale should become the centers of considerable mining and refining activity. Rifle, near the eastern line of the area, is the starting point for mail and freight routes to Meeker and the White River country, to the north, and the place where nearly all the supplies for that part of Colorado leave the railroad. Meeker, 44 miles north of Rifle, is in the center of an immensely rich agricultural region where among other things are grown some of the best oats and wheat known in Colorado, Utah, or Wyoming. Meeker is the distributing point for nearly all the country tributary to White River. Rangely, 60 miles down the river from

Meeker, is a small ranch town best known because of its connection with the Rangely oil field, near by. Although a large number of wells have been drilled in this field, its long distance from a railroad and the relatively small size of the wells has prevented it from making more than a very small production. Colbran, Mesa, and Plateau City, three small towns in the valley of Plateau Creek south of Battlement Mesa, provide local trading centers for a considerable area of rich agricultural and stock-raising country. These towns are connected with De Beque and Palisade by excellent automobile roads. Cameo, near the mouth of Plateau Creek, is a busy coal-mining camp.

The fourth area, which is a part of the Red Desert Basin of southern Wyoming, lies north of Yampa River, in territory tributary to Little Snake River, and has not been examined; the limits and richness of the shale in that area are therefore largely matters of guess.

In northwestern Colorado the most valuable oil shales, because of their richness, thickness, and nearness to railroad transportation, are those exposed in the Parachute Cliffs, near Grand Valley and De Beque. The oil shales in the northern part of the area are less rich and in most places dip at greater angles than those along the southern rim, and mining of them will therefore involve expenses not necessary in the nearly horizontal shales of the De Beque and Grand Valley region.

After a careful study of the thickness and oil-yielding capacity of the shales exposed in each of the localities where sections have been measured, it is estimated that if 60 per cent of the total shale in northwestern Colorado existing in the ground as beds 3 feet or more thick and yielding at least 15 gallons of oil to the ton were treated in retorts it would produce a total of 40,640,000,000 barrels (42 gallons each) of crude shale oil. If 60 per cent of the nitrogen in the shale that is treated is converted into ammonium sulphate, the yield of this substance should approximate 400,000,000 tons.

PICEANCE CREEK BASIN.

GEOGRAPHY.

The area here designated the Piceance Creek basin is a topographic basin in Garfield and Rio Blanco counties drained almost wholly by Piceance Creek and its tributaries. The basin is bounded on the east by the Petrolite Hills, which stand at altitudes of 7,500 and 8,000 feet above sea level. On the north the basin ends at a low ridge along the south side of White River, through which Piceance and Yellow creeks have cut rather narrow gorges. Its western rim is marked by the Cathedral Bluffs, which present a steep western face where the oil-shale beds are exposed and which separate the Piceance Creek basin from the Douglas Creek basin, to the west. The altitude of the Cathedral Bluffs ranges from

8,300 to 8,800 feet. On the south the Piceance Creek basin is limited by the southward-facing Parachute Cliffs (see Pl. IX), which in the vicinity of Rifle and Grand Valley rise in almost vertical walls about 3,000 feet above Grand River, only 2 or 3 miles away. Until very recently these cliffs, which extend from Rifle to the west line of the State, 60 miles to the west, could not be crossed even on foot except at half a dozen places. Parachute Creek, from which the cliffs derive their names, and Roan Creek, to the west, have excavated deep, narrow gorges (see Pl. X) back into the shale area, and the canyon of each of these streams and its tributaries ends abruptly in a sheer wall several hundred feet high at the outcrop of the oil-shale beds (see Pl. XI). Before the beginning of the development of the oil shale (1917) the excellent grazing lands above and back of these cliffs were reached from the fertile farms in the valleys below by only a scant half dozen very steep and crooked stock trails, over which pack trains were taken with great difficulty. Even now there is no wagon road open for travel connecting these two adjacent but still completely separated areas. The one wagon road that crosses the cliffs connects the ranches on Douglas Creek with the Denver & Rio Grande Western Railroad at Fruita and does not provide a route open to those wishing to enter the upland country above the shale cliffs. Back of the cliffs the surface is rolling and makes most excellent summer grazing land, but on account of the severe winter in this high altitude (8,000 to 9,000 feet above sea level) the cattle that use the upland pasture in the summer are brought down into the lower country to pass the cold weather. Small patches of spruce timber are to be found here and there in the canyons (see Pl. XI) and form a valuable asset to the region, for some of the trees are large enough for saw logs, and many of them are valuable for ties and mine props. Excellent water springs forth at the head of nearly every small valley in the land above the oil-shale beds and cliffs, and many of the larger springs, such as the Figure Four Spring and the springs near the heads of Sulphur and Duck creeks, are well known to cattlemen of the region.

A dozen or so ranches are to be found along the valley of Piceance Creek, two or three along Douglas Creek, and a very few newly established so-called dry farmers back of the cliffs on the west side of Parachute Canyon, but aside from these the basin is practically unoccupied except by the cow-punchers during the summer, when it is possible to use the range for cow pasture. The valley of White River to the north of the basin is under irrigation, and the narrow valley areas along Parachute and Roan creeks are likewise used for the cultivation of alfalfa, potatoes, and small grains. Along these streams there are many old and well-established farms. Excellent

fruit (apples, peaches, melons, etc.) is raised on the lands in the valley of Colorado River, especially near Grand Valley and Pallisades.

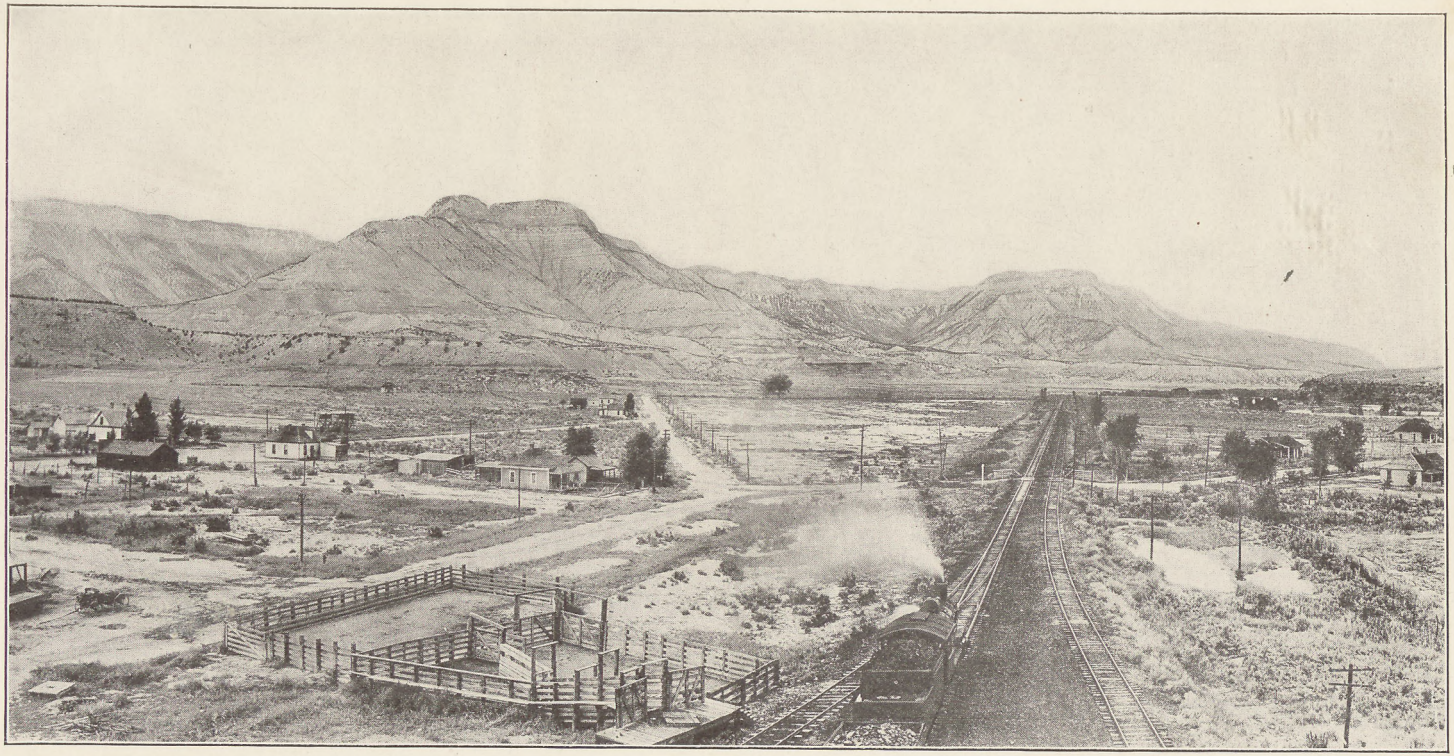
Two routes provide access to the the country on the north, back from the valley of Colorado River. From Rifle, on the Denver & Rio Grande Western Railroad, an excellent auto road runs north to Meeker, 44 miles, thence down White River to Rangely and beyond to the Uinta Basin country in northeastern Utah. The second route is by the narrow-gage Uintah Railway from its junction with the Denver & Rio Grande Western at Mack, 20 miles west of Grand Junction, over the Parachute Cliffs at Baxter Pass and down Evacuation Creek to Dragon and Watson, Utah, from which roads lead to the ranches on Douglas Creek and to Rangely, on White River, as well as to Vernal and other points in northeastern Utah. The development of the oil-shale lands of the basin will probably necessitate the construction of additional railroads into the region, and it is quite probable that even in the near future branch lines of the Denver & Rio Grande Western Railroad will be built up Parachute and Roan creeks and perhaps up some of their larger tributaries. The construction of spurs up these canyons should be comparatively easy and inexpensive. (See Pl. XII.)

STRATIGRAPHY.

The youngest sedimentary rocks in the Piceance Creek basin belong to the Green River formation, which also carries most of the oil shales. Beneath the Green River formation and outcropping in the area immediately surrounding it on all sides is the highly colored Wasatch formation, and this in turn is underlain by the Mesaverde formation, which in this part of the State contains thick beds of good bituminous coal.

No clear-cut and persistent line has been observed separating the Green River from the underlying Wasatch; in fact, there is evidence to support the view that sedimentation was continuous throughout the period represented by these two Eocene formations. The boundary shown on the map is only approximate and represents the line between the highly colored beds below (Wasatch) and the predominantly gray beds above (Green River). In some parts of the field this change in color takes place about 1,000 to 1,200 feet below the rich oil-shale zone; in others it is only 500 to 600 feet below the oil-shale beds.

The Green River formation is the surface rock over the entire interior part of the Piceance Creek basin, except in a very small area on top of the high mesa west of Grand Valley, where lava is present. The presence or absence of rich oil-yielding shales permits a division of the Green River formation into three members. The upper member, which gives rise to rounded topographic features, is composed largely



PARACHUTE CLIFFS, EAST OF GRAND VALLEY, COLO.

EXPLANATION

- Qal — Alluvium — QUATERNARY
- Tgr — Green River formation — Eocene — TERTIARY
- Tw — Wasatch formation — Eocene — TERTIARY
- Horizontal bed
- Strike and dip

R. B. Marshall, Chief Geographer.
Sledge Tatum, Geographer in charge.
Topography by A. P. Meade, Jr., and F. H. Nelson.
Control by C. F. Urquhart and C. H. Semper.
Surveyed in 1910.

Geology by E. G. Woodruff

Scale 1/62,500

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

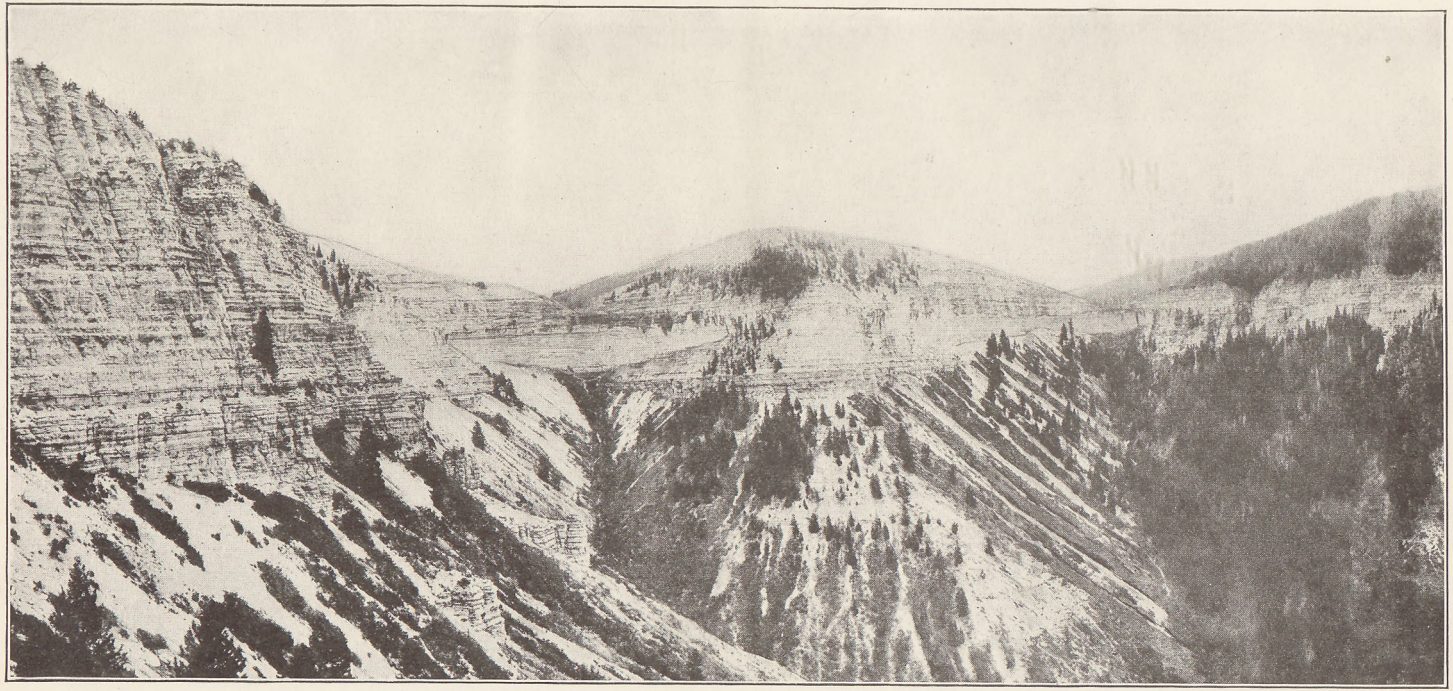
Contour interval 50 feet.

Datum is mean sea level.

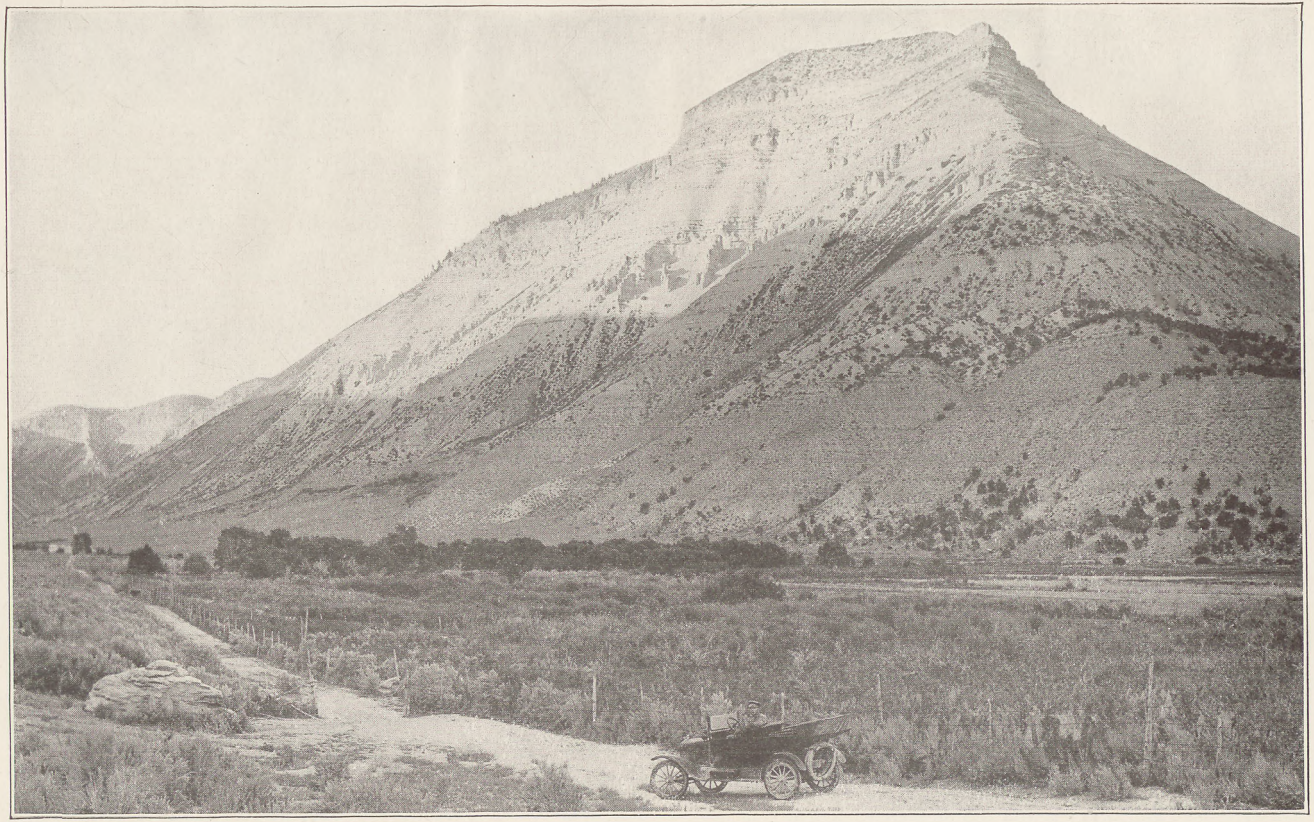
APPROXIMATE MEAN DECLINATION 1910.

MAP OF THE DE BEQUE OIL FIELD, COLORADO

SHOWING GEOLOGIC FORMATIONS AND STRUCTURE

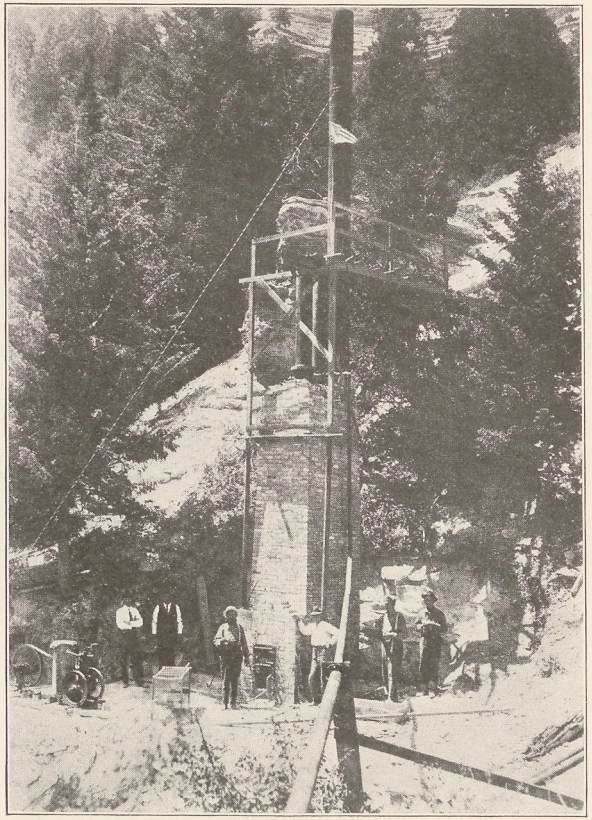


OIL SHALE IN PARACHUTE CLIFFS AT HEAD OF COTTONWOOD GULCH, COLO.



PARACHUTE CLIFFS ON EAST SIDE OF CONN CREEK, NORTH OF DE BEQUE, COLO.

A. RICH OIL SHALE IN PARACHUTE CLIFFS NEAR HEAD OF PARACHUTE CANYON, NORTH OF GRAND VALLEY, COLO.



B. OIL SHALE MINING CO.'S FIRST RETORT, ON DRY FORK, WEST OF DE BEQUE, COLO.

of soft shales with some sandstone and includes but few beds of rich oil-yielding shale. The middle member almost everywhere along its outcrop includes beds of rich oil shale, which in some places have a great aggregate thickness (see Pl. XIII, *A*) and which are everywhere extremely resistant and stand out in relief. In the Parachute Cliffs and the Cathedral Bluffs this middle member presents a nearly vertical and in most places impassable wall 500 to 1,000 feet high. Interbedded with the rich oil shale are beds of lean and almost barren shale and sandstone of varying thickness, and in some places these thin beds are remarkable because of their regularity and persistence.

As is shown by the stratigraphic sections given below, there are in nearly every section many beds of shale that will yield at least 15 gallons of crude oil to the ton, but the correlation of beds from one measured section to another, although the sections may be only a few miles apart, is very uncertain. A careful study of the strata exposed in a continuous cliff face a mile or more in extent shows that although the formation appears to be remarkably regular in thickness, individual beds vary greatly from place to place and that a single massive bed 5 feet thick at one place may change to comparatively thin-bedded shale within less than half a mile. One zone of oil-producing shale near the mouth of Piceance Creek was examined, carefully measured, and sampled at three localities within a distance of approximately 1,100 feet along its outcrop to determine its variability in thickness, bedding, mode of weathering, and value as a source of oil, with the following results:

Sections of oil-shale zone along the west side of Piceance Creek in sec. 11, T. 1 N., R. 97 W., Colorado.

Location 34.[9]

	Ft.	in.
Shale, hard, black	1	2
Shale, light brown		3
Shale, dark brown		2
Shale, light brown		1
Shale, hard, black		7
Shale, light brown		½
Shale, hard, black, in beds 2 inches thick		6
Shale, brown		2½
Shale, hard, dark		2
Shale, brown, lean [10]		2
Shale, hard, dark		3
Shale, brown		½
Shale, hard, dark		1
Shale, lean		4½
Shale		1
Shale, hard, black	1	2
	5	4

[9] Location numbers correspond to those used on the maps. Stratigraphic sections are arranged so that the youngest beds are described first and successively older beds follow.

[10] In this paper the term "lean" is applied to shale that will yield less than 15 gallons of oil to the short ton, and "rich" to shale that will yield more than 15 gallons.

Location 35, 100 feet N. 7° E. of location 34.

	Ft.	in.
Shale, dark brown		2
Shale, hard, dark brown		2
Shale, hard, black		1½
Shale, sandy, lean	1	4
Shale, brown, rich		5
Shale, hard, brown		3
Shale, brown, rich		11
Shale, hard, brown		2
Shale, rich		3
Shale, hard, brown		1½
Shale, brown, lean		3
	4	2

Location 36, about 1,000 feet N. 10° E. of location 35.

	Ft.	in.
Shale, hard, dark		1
Shale, brown, thin bedded		1
Shale, hard, dark		4½
Shale, lean		½
Shale, hard, black		5½
Shale, brown		¼
Shale, hard, black		4
Shale, brown		1½
Shale, hard, black		8½
Shale, brown		½
Shale, hard, black		4½
Shale		1
Shale, hard, black		3
Shale, brown, lean		4
	3	3¾

Samples from these localities when subjected to distillation gave the following results:

Results of distillation of samples from three localities on a single bed of shale on the west side of Piceance Creek, sec. 11, T. 1 N., R. 97 W.

Location No.	Total thickness sampled.	Yield of oil per ton of shale.	Gravity of oil.	
			Specific.	Baumé (°).
	Ft. in.	*Gallons.*		
34	5 4	23.0	0.888	27.6
35	4 2	14.7	.887	27.9
36	3 3¾	31.0	.883	28.5

This zone contains shale which on weathering resembles somewhat closely a massive bed but which, as seen upon close examination, may be subdivided into a number of very thin units differing from one another only in minor particulars. The gravity of the oil derived from these samples is fairly uniform, but the quantity differs widely. It is possible that part of this difference in yield may be due to changes produced by weathering, although if such were the case it would seem that the gravity of the oil in sample 35 would show a corresponding increase. However, the data at hand are not sufficient to make generalizations.

In many places massive beds of dark, tough, rich shale contain lenses of coarse sand that show no free oil. In other places small masses (some of them mere films between beds) of solid black hydrocarbon are found in the shale. Hydrocarbon occurring in this way in a small gulch east of of Piceance Creek near its mouth possesses

all the properties of elaterite, but in most places the material is similar to gilsonite. In sec. 14, T. 1 N., R. 97 W., this elaterite may be seen at a number of places between two beds of rather rich shale. In some places, such as Hay Gulch, in sec. 36, T. 1 N., R. 96 W., there are pockets of black material which have the shape of partly compressed stems but which show no woody structure, as would be expected if they were carbonized wood. The material contained in these pockets is not soluble in ether, chloroform, gasoline, or turpentine, the ordinary solvents of hydrocarbons.

The beds below the principal oil-shale member of the formation have the same general gray-white appearance as the oil shale but include more irregularly bedded sandstones and shales, with which in nearly every exposure are one or more thin beds of oolite and conglomerate. No rich oil shale is ordinarily found in this part of the section, although nearly all of the shale will yield some oil, and except for the sharp change in color between beds that are here classified as Green River and beds that are tentatively classified as Wasatch, there seems to be no reason to separate the two formations, for there is everywhere a rather complete gradation from the very coarse, lenticular beds of the lower formation to the remarkably fine-grained and even-bedded deposits of the upper formation.

In the Wasatch formation as the term is here used are included all beds above the coal-bearing yellow sandstones of the Mesaverde formation and below the top of the highest beds of red shale. Some beds may be included in the formation which should properly be referred to the overlying Green River, inasmuch as the separation of the two formations is based on color alone. The Wasatch formation as thus defined is composed of coarse, irregularly bedded sandstones, conglomerates, highly colored red, green, and yellow clays, thin-bedded shales, some of which will yield oil when distilled, and thin lenticular beds of low-grade coal. In the Petrolite Hills some of the beds of coarse sandstone near the top of the Wasatch formation are saturated with asphaltic material, and at De Beque wells drilled for oil have obtained small quantities of high-paraffin oil from sands near the base of the formation.

STRUCTURE.

The rocks at their outcrop around the edges of the Piceance Creek basin dip at low angles toward the center of the basin. In the Cathedral Bluffs dips of 3°–6° E. are common, and the beds hold this attitude in most places for at least 5 miles back of the outcrop of the rich oil shale. Along the north side of the basin the oil-shale beds show dips to the south as high as 20°, but the dip decreases rapidly back of the outcrop. Along the eastern margin of the basin shales

referred to the Green River formation dip as much as 27° W., but here also the dip decreases very rapidly, so that a mile or two back of the outcrop the beds are nearly horizontal. East of the outcrop of the oil-shale beds older formations are upturned more steeply, so that in the Grand Hogback, only about 2 miles away, the massive resistant sandstone of the Mesaverde formation is tilted at angles as great as 90°.

Along the southern margin of the basin and across Colorado River in Battlement Mesa the oil-shale beds are more nearly flat than elsewhere but have a slight northward dip.

Very little faulting has taken place in this area, and such breaks as have been discovered are more in the form of cracks in which vertical displacement is not noticeable. Such cracks are usually filled with hydrocarbon materials which at one time may have been liquid. One of the most interesting occurrences of this type is in Jessup Gulch, a tributary of Piceance Creek on the west side of the Petrolite Hills. Here a fracture zone 2 or 3 feet wide is filled with a yellowish-brown hydrocarbon which is of low specific gravity and is entirely different in physical appearance from the ordinary asphaltite. The deposit may not be sufficiently extensive to be of economic importance, but its unusual characteristics make it of considerable scientific interest.

BATTLEMENT MESA.

GEOGRAPHY.

Immediately south of Colorado River and the town of Grand Valley the surface rises rather rapidly in what is known as Battlement Mesa, upon which are some of the richest farms of the area. Surmounting the mesa proper is a high, rugged upland bordered by steep slopes and cliffs containing the oil shale of the Green River formation. This upland is for the most part covered by lava and lava boulders, over which in most of the area there is a dense timber growth. Surfaces of angular lava blocks such as are present here are practically impassable to man or beast. North Mam and South Mam peaks rise above this generally high and impassable country as pinnacles nearly 11,000 feet above sea level. The north faces of the upland areas are in most places covered with dense underbrush and timber, so that except in a few cut cliffs there are no natural exposures of the oil-shale beds. The south face of the upland, however, is for the most part bare, and the shale beds are well exposed. Castle Rock, a small but conspicuous pinnacle, forms the westernmost outcrop of the oil-shale rock in this Battlement Mesa country.

GEOLOGY.

In Battlement Mesa the brightly colored Wasatch formation is exposed in the lower areas, and the Green River, containing the oil-shale beds, forms the steep cliffs of the upland and is in turn overlain by the more recent lava, which probably was poured out over the surface from vents now represented by the Mam peaks. Had the molten lava been poured out over a surface only a few feet above the oil-shale beds, the volatilizable constituent of the shale would doubtless have been driven off and the shale ruined, but the interval of 500 to 1,000 feet which separates the rich oil shale from the lava has probably prevented any such devolatilization. Doubtless, however, there is a considerable zone of impoverished shale surrounding the vents through which the lava was brought from its deep-seated source. Until underground mining furnishes the data, the area of this devolatilized shale will remain one of the earth's secrets. In Battlement Mesa the beds of the Green River formation appear to dip uniformly northward at very low angles.

GRAND MESA.

GEOGRAPHY.

South of Battlement Mesa and separated from it by the valley of Plateau Creek is the high lava-covered Grand Mesa, which is one of the most conspicuous topographic features of the region. Its upper surface is rough and in most places timber covered. Numerous beautiful natural lakes are scattered over the mesa, and several larger lakes have been formed by the damming up of natural reservoir sites and store water for the irrigation of large tracts of fertile land on either side of the mesa. The slopes of the mesa are in most places deeply covered with timber and brush, so that there is little opportunity to study the geologic formations.

South of Plateau Creek the surface rises gradually toward Grand Mesa, but the soil in this area is very productive and as a result there are many excellent farms on which fine crops of grain, alfalfa, potatoes, and fruits are grown. This area is in fact one of the most thickly populated portions of the region covered by the map. Colbran, one of the older towns of this part of the State, is on Plateau Creek in T. 9 S., R. 95 W., and serves as the trading center for a large area. Mesa, in T. 10 S., R. 96 W., is a lively small town on the bench back from Plateau Creek. Both these towns are connected by excellent automobile roads with De Beque and Palisade, and mail is brought to them daily from De Beque by auto stage.

GEOLOGY.

The valley of Plateau Creek and most of the slopes well up toward Grand Mesa are occupied by the brightly colored rocks of the Wasatch formation, and the steeper slopes of the mesa contain shales of the Green River formation. These shales are not exposed except at a very few places along the north side, and it is impossible to say whether or not the oil shales that have been prospected on Big Creek near the forest-ranger station belong to the rich zone of the Parachute Cliffs, but largely because of the leanness and thinness of the beds there exposed it is thought that they represent some of the oil shales in the lower part of the formation. Up to the time of the writer's visit to Grand Mesa in 1918 no oil shales that appeared commercially attractive had been discovered. On the south side of the mesa beds thought to be of Wasatch age are the first exposed beneath the lava cap rock.

Overlying the Green River beds and capping the mesa is a great thickness of lava, which of course prevents a study of the Green River beds at their southern limit.

STRATIGRAPHIC SECTIONS AND SAMPLES.

The following stratigraphic sections were measured at places indicated on the map (Pl. VIII, in pocket) and illustrate the character of the rocks exposed in different parts of the field. The beds of shale that are known by testing or are estimated to yield 15 gallons of or more to the ton of shale are indicated by heavy type in the sections.

Sections in northwestern Colorado.

Location A, T. 2 N., R. 104 W.

	Ft.	in.
Shale, gray, with a few hard sandstone beds each a few inches thick	350	
Sandstone, white	1	
Shale, gray	60	
Sandstone, clayey	15	
Shale, thin bedded, with a few thin beds of sandstone	15	
Shale, brown to black; contains thin beds of rich oil shale	2	
Shale, thin bedded, slightly carbonaceous, but is supposed to yield very little oil	30	
Shale, brown, thin bedded; will probably yield some oil	1	
Shale, brown; will probably yield some oil	2	
Shale, gray, thin bedded	18	
Shale, thin bedded, brown; contains thin laminae of oil shale	10	
Shale, sandy	40	
Shale, dark brown, rich in oil		4
Shale, light gray, sandy	7	
Shale; will yield a little oil	1	

Location A, T. 2 N., R. 104 W—Continued.

	Ft.	in.
Shale, gray	2	
Shale, dark brown, rich in oil		4
Shale, slightly sandy	7	
Sandstone and shale; sandstone shows ripple marks as much as 6 inches from crest to crest	15	
Sandstone, coarse, containing concretions	3	
Sandstone, clayey	5	
Shale, sandy	50	
Sandstone and shale, about 60 per cent sandstone; sandstone for the most part ripple marked; one thin bed of carbonaceous shale	90	
Sandstone, conglomeratic at the base; most of the pebbles are flat; some are 4 inches across	2	
Sandstone, thin bedded, not resistant	15	
Shale, sandy	24	
Sandstone, ripple marked; ripples 4 inches from crest to crest and three-quarters of an inch deep	3	
Shale, sandy	10	

Location A, T. 2 N., R. 104 W.—Continued.

	Ft.	in.
Sandstone, friable, with about 10 per cent of shale; sandstone is oolitic	3	
Sandstone, friable, with about 33 per cent of shale	54	
Sandstone, thin bedded	15	
Shale, gray	25	
Sandstone, shaly	1	
Shale, sandy	15	
Sandstone, coarse grained	3	
Shale	75	
Oolite with grains as large as one-sixteenth of an inch; this stratum is a massive ledge maker, the most resistant rock of the formation	5	
Shale, sandy	62	
Sandstone, thin bedded	5	
Shale, gray, mostly covered	114	
Sandstone, thin bedded, cross-bedded, and slightly conglomeratic; the grains are mostly silica and well rounded	10	
Shale, gray	50	
Sandstone, conglomeratic; largest pebbles observed have a maximum diameter of one-half inch		3
Shale, gray	26	
Sandstone, shaly	3	
Shale, gray	20	
Surface covered, supposed to be mostly shale; tan-colored shale exposed at base	280	
Sandstone, white, lenticular	3	
Shale, drab; contains some sand	204	
Sandstone, tan-colored		6
Shale, sandy	120	
Sandstone, tan-colored, definitely Wasatch; bottom of section.		
Total section	1,872	5
Total shale yielding more than 15 gallons to the ton		8

Location B, T. 1 N., R. 103 W.

	Ft.	in.
Shale, evenly thin bedded, with very little sandstone	250±	
Shale, dark, thin bedded; estimated that at least 50 per cent is oil-bearing shale (sample 10 from bed 3 feet 10 inches thick near top; 11.3 gallons)	50	
Shale, sandy, thin bedded, lean	11	
Sandstone		4
Shale, thin bedded, sandy in places, bituminous in others; will yield some oil	7	
Shale, dark brown; weathers bluish gray, rich		7
Sandstone, shaly	5	
Sandstone, friable; weathers to round forms	1	
Shale, hard, dark brown, rich (sample 8; 4.26 gallons)	1	
Shale, light brown (sample 8; 4.26 gallons)	3	8
Shale, alternating beds of rich oil-bearing shale (estimated 10 per cent) and lean shale	7	
Shale, clayey, containing thin beds of rich oil shale	4	

Location B, T. 1 N., R. 103 W.—Continued.

	Ft.	in.
Shale, thin bedded	5	
Shale and sandstone, containing some oil-bearing layers; the entire member is colored red by burning	45	
Shale, sandy; contains some thin sandstones	5	
Shale, sandy	10	
Shale, dark brown, hard; weathers bluish gray; rich	1	
Shale, clayey, thin bedded; contains a few thin layers of rich shale	19	
Shale, sandy	3	
Shale, thin bedded, clayey		8
Shale, sandy; contains some bituminous matter	1	
Shale, with thin beds of rich oil-bearing shale; estimated that 50 per cent is rich rock	4	
Shale, sandy	11	
Shale, dark brown; weathers bluish gray; rich	2	6
Shale, sandy, thin bedded, calcareous	4	
Shale, carbonaceous; contains beds of rich shale as thick as three-quarters of an inch (sample 12; 8.64 gallons)	2	3
Sandstone, ripple marked at top, thin bedded	7	
Shale	3	1
Shale, lean	1	11
Shale, dark brown; contains disseminated iron sulphide (sample 11; 8.22 gallons)	1	11
Shale, thin bedded, brown		9
Shale, sandy	6	
Shale, dark brown, massive, rich	4	
Shale, gray, lean; contains some bituminous matter	4	
Sandstone, thin bedded	5	
Shale, sandy	7	
Sandstone, even bedded	2	
Shale, grading into sandstone at the top	7	
Shale, dark brown, with disseminated iron sulphide, rich	1	
Shale, sandy at base, thin bedded at top	9	
Sandstone, thin bedded	3	
Shale, sandy	9	
Shale, thinly laminated, dark brown on fresh surface; contains beds of rich shale	7	
Shale, sandy	2	
Shale, thinly laminated, dark brown on fresh exposure; probably will yield some oil	8	
Shale, dark brown, thin bedded, rich	1	
Shale, sandy	13	
Sandstone, thin bedded, ripple marked	2	
Shale, sandy; in places will yield oil	4	
Shale, dark brown; weathers bluish gray; rich		2
Shale, sandy	7	
Sandstone, thin bedded, with some shale	7	
Shale, lean	18	
Sandstone, cross-bedded at top	3	
Sandstone and shale	25	

Location B, T. 1 N., R. 103 W.—Continued.

	Ft.	in.
Sandstone, in beds having a maximum thickness of 4 inches	5	
Shale, with some sandstone; shale is dark and carbonaceous; probably will yield some oil	33	
Conglomerate; maximum size of pebbles half an inch		8
Shale, drab	25	
Shale, brown; slight oily odor		4
Shale, dark brown; weathers blue		1½
Shale, light brown; weathers platy		5
Shale, dark brown, hard; weathers blue	(sample 7; 12.6 gallons).	
Shale, dark brown, hard; weathers blue		2
Shale, soft, brown; weathers into fine laminæ and curls on surface	1	
Shale	50	
Oolite		4
Sandstone and shale	25	
Oolite		6
Shale and sandstone in layers as thick as 6 inches	40	
Shale, finely laminated; gives slight oily odor when broken	8	
Sandstone, calcareous		6
Shale; lower part drab; upper part weathers curly	13	
Limestone	2	
Shale, mostly drab, partly carbonaceous, finely laminated	33	
Shale, thin bedded, rich; gives slight oily odor when freshly broken	5	
Sandstone, containing clay balls		2
Shale, drab	25	
Shale, sandy	3	
Sandstone, containing pebbles as large as half an inch in diameter		2
Shale, sandy	1	6
Shale, dark brown, rich; gives oily odor when broken		4
Shale, thick bedded, rich	2	10
Shale, finely laminated, brown, carbonaceous	2	6
Shale, thick bedded, rich; gives oily odor when broken	3	
Shale	12	
Sandstone, coarse grained		2
Shale	10	
Sandstone		5
Shale, thinly laminated, dark brown	3	
Talus slope at bottom.		
Total section	929	1½
Total shale yielding more than 15 gallons to the ton	26	7

Location C, on north side of White River, T. 1 N., R. 104 W.

	Ft.	in.
Shale, sandy; weathers to round forms	50	
Shale, light brown, lean		6
Interval, probably sandy shale	20	

Location C, on north side of White River, T. 1 N., R. 104 W.—Continued.

	Ft.	in.
Shale, dark brown; weathers bluish gray; rich		6
Shale	7	
Shale, dark brown; weathers bluish gray; rich	1	
Shale	3	
Shale, dark brown; weathers bluish gray; rich		6
Sandstone, thin bedded	15	
Shale, dark brown; weathers bluish gray; 75 per cent rich shale and 25 per cent lean shale	8	
Shale, dark brown; weathers bluish gray; rich		8
Shale, brown, thin bedded	1	4
Shale, dark brown; weathers bluish gray; 75 per cent rich shale and 25 per cent lean shale	5	
Shale, dark brown; weathers bluish gray; about 10 per cent lean shale, remainder rich shale	5	
Shale, dark brown; weathers bluish gray; about 40 per cent rich shale	35	
Shale, dark brown; weathers bluish gray; about 10 per cent lean shale, remainder rich shale	1	
Shale	3	
Shale, dark brown; weathers bluish gray; about half rich shale and half lean shale	3	
Shale, sandy	4	
Shale, dark brown; weathers bluish gray; rich		6
Sandstone, massive	1	6
Shale, dark brown; weathers bluish gray; rich and lean shale interbedded	5	
Shale, sandy	23	
Sandstone, thin bedded	2	
Shale	20	
Shale, dark brown; weathers bluish gray; rich; contains an abundance of iron pyrite	1	
Shale; about 25 per cent rich, dark brown	2	
Shale, dark brown; weathers bluish gray; rich	2	
Shale	5	
Shale, dark brown; weathers bluish gray; rich	1	
Shale	9	
Shale, sandy; about 33 per cent rich, dark brown	13	
Shale, sandy	3	
Shale, dark brown; weathers bluish gray; rich	2	
Shale, dark brown; weathers bluish gray; rich; and sandy shale	1	
Shale, sandy	3	
Shale, dark brown; weathers bluish gray; rich	1	
Shale, drab, with thin layers of rich dark-brown shale	3	
Shale, dark brown; weathers bluish gray; rich		6
Interval, probably mostly shale	13	

Location C, on north side of White River, T. 1 N., R. 104 W.—Continued.

	Ft.	in.
Shale, dark brown; weathers bluish gray; rich	1	
Shale, sandy	5	
Sandstone	3	
Shale	7	
Shale, dark brown; weathers bluish gray; rich		1
Shale	4	
Shale, dark brown; weathers bluish gray; rich	1	2
Shale	35	
Sandstone, shaly	4	
Shale, light gray, sandy	4	
Shale; black; contains thin beds of rich dark-brown shale	1	
Shale, drab, with some thin beds of rich dark-brown shale near top	20	
Shale, dark brown; weathers bluish gray; rich; interbedded with lean shale	3	
Shale, thin bedded; 25 per cent rich dark-brown shale	6	
Shale, dark brown; weathers bluish gray; rich	2	2
Shale, with thin beds of rich dark-brown shale		6
Shale, dark brown; weathers bluish gray; rich	1	
Sandstone, shaly, grading to shale in the lower part	8	
Shale, dark brown; weathers bluish gray; rich		1
Shale, drab	27	
Sandstone, shaly	5	
Shale, sandy	23	
Shale, drab	20	
Shale, thin bedded, black on fresh surface, rich	4	
Shale, sandy	5	
Shale; weathers curly; will yield some oil		6
Shale	18	
Sandstone, shaly	5	
Shale	8	
Sandstone, brown		2
Shale	20	
Shale, dark brown; weathers bluish gray; rich	1	
Shale, gray, sandy at base, thin bedded at top	75	
Oolite, with grains as large as one-eighth inch in diameter		5
Shale, with some rich dark-brown shale	5	
Oolite		1
Shale, sandy, with some sandstone	13	
Oolite		1
Shale, upper part tan-colored, lower part gray	100	
Sandstone, light colored, with shaly layers and some rich dark-brown shale	4	
Shale, light colored at bottom, dark at top; some rich dark-brown shale	27	
Sandstone, including clay balls; a single fossil gastropod was found in this bed		4
Shale, drab	2	

Location C, on north side of White River, T. 1 N., R. 104 W.—Continued.

	Ft.	in.
Sandstone, at some places oolitic and at others slightly conglomeratic		8
Shale, dark	20±	
River.		
Total section	765	3
Total shale yielding more than 15 gallons to the ton	49	2

Location D, T. 1 N., R. 100 W.

	Ft.	in.
Shale, drab; contains sandy layers	40	
Shale, dark brown, rich		6
Sandstone	6	
Shale, dark brown, rich	1	
Sandstone, thin bedded	5	
Shale, drab	20	
Sandstone, thin bedded	3	
Shale, thin bedded, lean	15	
Sandstone; contains much crystalline quartz; weathers like an oolite		4
Shale, drab, with sandy layers	30	
Shale, dark brown, rich	3	
Shale, drab	35	
Shale, lean		6
Shale, sandy	4	
Shale; about 30 per cent rich shale in thin layers	4	
Shale, drab	3	
Shale, with a few streaks of rich dark-brown shale	5	
Shale, drab	30	
Sandstone, thin bedded	2	
Shale and thin sandstone; contains beds as thick as 2 feet which probably will yield some oil	45	
Shale, thin bedded, lean	10	
Shale, drab, slightly sandy	15	
Shale, thin bedded, lean	2	
Shale	30	
Shale, thin bedded, slightly carbonaceous; contains thin sandy beds	25	
Covered	65	
Total section	399	4
Total shale yielding more than 15 gallons to the ton	4	6

Location E, T. 1 N., Rs. 99 and 100 W.

	Ft	in.
Sandstone, yellow, slightly friable; contains concretions of pyrite	15	
Sandstone, argillaceous, and sandy shale, mostly thin bedded; a little biotite	20	
Shale; upper part slightly sandy; contains some mica; lower part not well exposed	120	
Shale, dark gray to brown; contains a few beds of bituminous shale about half an inch thick	65	
Shale, gray, calcareous, in beds about 2 inches thick	8	
Shale, gray to brown, slightly bituminous	20	
Shale, dark brown, rich		8

Location E, T. 1 N., Rs. 99 and 100 W.—Continued.

	Ft	in.
Shale, thin bedded, gray on weathered outcrop but contains thin beds of brown and black rich bituminous shale; estimated that 10 per cent of the rock will yield oil	18	
Shale, dark brown, thin bedded, 75 per cent rich and 25 per cent lean	1	
Shale; estimated 15 per cent rich oil shale	20	
Shale, gray on outcrop; top sandy, in beds 2 inches thick	20	
Shale, thin bedded; probably 15 per cent rich oil shale	10	
Shale, thin bedded, papery; estimated 75 per cent rich oil shale	7	
Shale, sandy; contains few carbonaceous layers	5	
Shale, thin bedded, estimated 50 per cent rich oil shale	1	6
Shale; contains little rich bituminous shale, but the whole is brown on fresh surface and probably will yield oil	1	
Shale, sandy, thin bedded	4	
Shale, dark brown, rich		1
Shale, thin bedded, lean		6
Shale, thin bedded, dark brown, rich	2	
Shale, sandy	2	
Shale, for the most part thin bedded, gray on weathered outcrop; probably 20 per cent of the whole is shale which will yield oil	13	
Shale, dark brown, massive; resists weathering; rich	2	
Shale, massive (estimated yield, 20 gallons)	4	
Shale, light gray, slightly sandy and bituminous	45	
Shale, dark brown, rich		1
Shale, thin bedded, lean	18	
Shale (estimated yield, 20 gallons)		6
Shale, gray on weathered surface, thin bedded, lean	43	
Sandstone, with numerous dark specks		2
Shale, sandy	7	
Shale, dark brown; about 67 per cent rich and 33 per cent lean	1	
Shale, drab	1	
Shale, dark brown; appears to be very rich (sample 13; 33.6 gallons)	5	
Shale, about 50 per cent oil shale	2	
Shale, sandy	33	
Shale, dark brown, rich	1	3
Shale	2	6
Shale, thin bedded, slightly carbonaceous but will probably yield some oil		6
Shale, gray, thin bedded	15	
Shale, dark brown, rich		6
Shale		8
Shale, dark brown, rich	6	
Shale, thin bedded	4	
Shale, dark brown, rich		2
Shale, thin bedded; contains possibly about 10 per cent rich shale	8	
Shale, dark brown, rich	1	

Location E, T. 1 N., Rs. 99 and 100 W.—Continued.

	Ft.	in.
Shale	6	
Sandstone, fine grained, massive		4
Shale	8	
Shale, dark brown, rich		2
Shale, gray, thin bedded	7	
Sandstone, shaly	2	
Shale, sandy	7	
Shale, dark brown, rich		8
Shale; contains some sandy beds	40	
Sandstone, yellow, shaly	15	
Shale and sandstone in about equal quantities	50	
Shale, dark brown, rich		6
Sandstone, shaly		8
Shale, dark brown, rich, with some sandstone lenses	1	
Sandstone, shaly	8	
Shale, very thin bedded (estimated yield, 25 gallons)	1	6
Shale, 25 per cent rich	1	
Shale, dark brown, interbedded with papery shale		6
Shale, drab	3	
Shale, lean		3
Shale, brown, thin bedded	6	
Shale, thin bedded (estimated yield, 15 gallons)	1	3
Shale, drab	7	
Sandstone, shaly	2	
Shale, dark brown (estimated yield, 25 gallons)	2	6
Shale, friable, yellow, lenticular	1	
Shale, drab	3	
Shale, very thin bedded (probable yield, less than 15 gallons)	2	
Shale, sandy	3	
Shale, thin bedded, with a few bituminous layers	10	
Shale, dark brown, rich, thin bedded (estimated yield, 35 gallons)	3	
Sandstone, contains quartz grains cemented with iron oxide		4
Shale, thin bedded	4	4
Shale, drab; contains sandy beds	5	
Shale, gray, sandy	10	
Shale, thin bedded, with some rich oil shale (estimated yield, 30 gallons)	5	
Shale, sandy	8	
Shale, thin bedded; will yield some oil	2	
Shale, sandy	7	
Shale, thin bedded, lean	5	
Shale, drab; some layers 1 foot thick; will yield oil	10	
Shale, dark brown, rich		4
Shale, thin bedded	4	
Shale, brown (estimated yield, 25 gallons)	3	
Shale, about 50 per cent bituminous	2	
Shale, thin bedded, bituminous	7	
Shale, thin bedded; contains rich bituminous layers; also sandstone lenses and lean shale	15	

Location E, T. 1 N., Rs. 99 and 100 W.—Continued.

	Ft.	in.
Sandstone, thin bedded	5	
Shale, thin bedded (estimated yield, 15 gallons)	3	
Sandstone, light-colored		2
Shale, dark brown; part rich and part lean	1	
Interval largely covered, but probably shale	40	
Total section	874	9
Total shale yielding more than 15 gallons to the ton	45	8
Total shale yielding more than 30 gallons to the ton	13	

Between the last bed mentioned above and the base of the Green River formation there is a distance of about 300 feet in which the rocks are largely concealed by surface material. It is probable, however, that there is considerable oil shale in this interval, but that it has been burned so as to lose its ordinary characteristics. The burning is indicated by loose fragments of red burned rock on the surface, by slaglike masses of fused material, and by black burnt-out shale exposed near the base of the formation.

Location F, T. 2 N., R. 98 W.

	Ft.	in.
Sandstone (about 75 per cent) and slightly bituminous shale	150	
Shale, gray, sandy; some layers brown on fresh surfaces	45	
Shale; about 20 per cent rich bituminous shale (samples 18, 19, 22, 23, and 24; 6.25 to 22.88 gallons)	5	
Shale, thin bedded, slightly bituminous, and sandstone	150	
Sandstone, minutely cross-bedded, massive	1	
Shale, drab; contains a few thin beds of sandstone	70	
Sandstone, massive; contains a few thin layers of conglomerate	2	4
Shale, in part slightly bituminous, with a few thin beds of sandstone	90	
Sandstone, in part chertlike		6
Shale, thin bedded	28	
Shale, dark brown, rich, and thin-bedded lean shale (estimated yield, 25 gallons)	5	
Shale, sandy, lenticular	3	
Shale, thin bedded (estimated yield, 15 gallons)	4	
Sandstone		6
Shale, dark brown, rich (sample 21; 26.8 gallons)		11
Sandstone, cherty (sample 21; 26.8 gallons)		2
Shale, dark brown, rich (sample 21; 26.8 gallons)	3	7
Sandstone and shale	1	
Conglomerate with pebbles half an inch in diameter		2
Sandstone and shale, with layers of rich oil shale 1 inch thick	8	
Shale and some sandstone	8	
Sandstone	1	

Location F, T. 2 N., R. 98 W.—Continued.

	Ft.	in.
Shale, gray, thin bedded	34	
Sandstone, slightly conglomeratic and oolitic		8
Shale, thin bedded (estimated yield, 25 gallons)	5	
Shale, dark brown (sample 20; 12.6 gallons)	3	
Sandstone, irregular in thickness, weathering light yellow		9
Shale, dark brown; weathers to papery shale (sample 14; 13.3 gallons)		5
Sandstone, shaly		8
Shale, light brownish drab; weathers to sheets one-eighth to three-eighths inch thick (sample 15; 3 gallons)	1	2
Sandstone, coarse, yellow		2
Shale, light brown (sample 16; 1.9 gallons)	1	4
Shale, dark brown, fairly rich; weathers papery (sample 16; 1.9 gallons)		8
Shale, hard, dark brown; weathers to blue resistant ledges; contains lenses of rock which weather yellow and resemble sandstone (sample 17; 21 gallons)		6
Sandstone; weathers rusty tan	9	
Shale (80 per cent) and sandstone; some beds of shale 1 foot thick may yield as much as 15 gallons of oil to the ton	40	
Shale (estimated yield, less than 10 gallons)	1	
Oolite		4
Shale, slightly bituminous		½
Oolite		2
Sandstone, thin bedded	5	
Oolite		2
Shale, slightly bituminous		½
Oolite		3
Sandstone, thin bedded, with some bituminous shale	58	
Shale, brown, lean, interbedded with thin sandstone	50	
Shale, brown to black, thin bedded, slightly bituminous	50	
Shale, brown, very thin bedded; weathers curly (estimated yield, 15 gallons)	1	
Sandstone, shaly	15	
Shale, brown, thin bedded; weathers curly (estimated yield, 15 gallons)	1	
Sandstone, shaly	8	
Shale, drab to gray, interbedded with thin beds of sandstone	90	
Shale, brown to black, thin bedded (estimated yield, less than 15 gallons)	25	
Shale, drab	10	
Shale, brown on fresh surface, thin bedded, slightly bituminous		8
Shale, tan-colored; weathers white; many of the joint planes, which are at right angles to the bedding, are filled with a siliceous deposit	2	
Shale, gray; weathers almost white; upper part thin bedded; some of the shale is slightly carbonaceous	20	
Shale, drab and tan-colored	100	

Location F, T. 2 N., R. 98 W.—Continued.

	Ft.	in.
Sandstone, light gray, fine grained, calcareous, ripple marked, lenticular	8	
Shale, drab and tan-colored	200	
Sandstone, ripple marked, lenticular	1	
Shale, sandy	15	
Sandstone, tan-colored, thin bedded	1	
Shale, drab	28	
Shale, tan-colored	50	
Oolite		6
Shale, tan-colored	20	
Sandstone, thin bedded		6
Shale, drab, thin bedded	40	
Sandstone, tan-colored, ripple marked, thin bedded	1	
Shale, with a few sandstone beds, tan-colored; Wasatch formation	200	
Total section	1,677	1¾
Total shale yielding more than 15 gallons to the ton	21	

Location G, T. 2 N., R. 97 W.

Top of hill.	Ft.	in.
Sandstone, massive, tan-colored, slightly friable, fairly coarse grained; weathers into nodular forms	5	
Shale, sandy	300±	
Shale, dark brown, rich		½
Shale, sandy	30	
Shale, dark brown (probable yield, 10 gallons)	1	
Shale, drab, thin bedded	50	
Shale (estimated yield, 20 gallons)	3	
Shale, thin bedded, sandy	25	
Shale, dark brown, rich	1	
Shale, sandy	45	
Sandstone	3	
Shale	5	
Shale, dark brown, rich		½
Shale, sandy	100	
Shale (estimated yield, 25 gallons)	3	
Shale, drab, with some sandy beds, lean	60	
Shale, generally lean, but with some rich layers	1	
Shale (80 per cent) and sandstone (20 per cent)	20	
Shale, thin bedded, containing thin layers of rich shale (probable yield of the whole, 15 gallons)	5	
Shale, drab, with some sandy layers	20	
Shale, sandy	10	
Shale, dark brown, with some lean beds (estimated yied of the whole, 25 gallons)	2	
Sandstone, shaly	1	
Shale, dark brown (estimated yield, 20 gallons)	2	
Shale, lean, oolite, and sandstone, intimately interbedded; oolite and sandstone lenticular	3	
Sandstone, shaly	3	
Shale, drab	4	
Sandstone	7	
Sandstone, shaly	10	

Location G, T. 2 N., R. 97 W.—Continued.

	Ft.	in.
Shale, with some thin beds of sandstone; part of the shale is carbonaceous; other parts will probably yield a little oil	40	
Interval, mostly covered but probably shale	50	
Shale, thin bedded (estimated yield, 15 gallons)		
Shale, carbonaceous, containing beds as thick as 6 inches which will yield oil		
Shale, sandy	15	
Shale (estimated yield, 25 gallons)	5	
Shale (estimated yield, 20 gallons)	2	
Shale, thin bedded, mostly carbonaceous; some parts are flexible and probably will yield oil; benches as thick as 2 feet are estimated to yield 25 gallons	30	
Shale, sandy, in places carbonaceous	25	
Shale, for the most part drab and thin bedded; contains beds as thick as 1 foot which will probably yield 20 gallons	30	
Shale, 10 per cent dark brown, rich, and 90 per cent lean	2	
Shale, thin bedded (possible yield, 15 gallons)	10	
Shale, carbonaceous	3	
Covered, probably mostly shale	100	
Shale, curly; contains lenses of bituminous sandstone (samples 25 and 26, lower 8 feet of this bed; 4.78 and 3.85 gallons)	15	
Shale, carbonaceous and sandy	2	
Sandstone		4
Shale, thin-bedded, carbonaceous; will probably yield a small quantity of oil	3	
Interval, probably mostly lean shale but with a few thin beds which are rich in oil	60	
Shale, thin bedded (estimated yield, 15 gallons)	3	
Sandstone		½
Shale, thin bedded, black on fresh surface (estimated yield, 25 gallons)		8
Interval, covered, probably shale	6	
Shale, dark gray to black, thin bedded (estimated yield, 25 gallons)	3	
Interval, mostly covered but probably sandy shale	20	
Oolite		10
Shale, thin bedded, brown on fresh surface, with sandstone beds as thick as 1 foot near the base (top includes beds estimated to yield less than 15 gallons)	15	
Shale, thin bedded, brown on fresh surface; contains lenses of sandstone	4	
Interval, covered but probably shale	15	
Sandstone and sandy shale; the sandstone, especially in the upper part, is oolitic	13	
Sandstone, mostly friable; contains beds which weather rusty	15	
Shale	3	

Location G, T. 2 N., R. 97 W.—Continued.

	Ft.	in.
Sandstone and oolite	3	
Sandstone, friable	2	
Shale, upper part sandy, lower part slightly carbonaceous in places	15	
Oolite and sandy shale	3	
Sandstone, shaly	8	
Sandstone, with oolitic phases	3	
Sandstone, shaly, friable	3	
Oolite	17	
Sandstone, friable	10	
Oolite	20	
Sandstone, shaly	15	
Shale and sandstone, folded and faulted to such an extent that detailed measurements are not possible. The folding and faulting are believed to be confined to this member. Some of the shale will probably yield oil	100	
Sandstone, tan-colored, slightly cross-bedded; contains oolitic layers near the top	17	
Sandstone, friable; contains a few thin lenses of oolite near the base	15	
Sandstone, with lenses of oolite averaging about 2 inches long	1	
Sandstone, shaly; cut by normal faults having throws of 6 to 8 feet; fault planes dip about 50° S.; ripple marks were noted in the highest and lowest layers of the bed	3	
Interval, mostly covered, probably sandy shale	40	
Sandstone; contains oolitic phases	5	
Sandstone, shaly	1	
Sandstone, oolitic	5	
Sandstone, shaly	3	
Sandstone, minutely cross-bedded; top oolitic	5	
Sandstone, shaly	1	
Oolite	15	
Sandstone, oolitic	2	
Shale, sandy, but contains carbonaceous beds, also sandstone layers as thick as 2 inches	25	
Oolite, containing numerous gastropods at the base	8	
Sandstone, shaly at the base, gray on unweathered surface	3	
Shale, slightly gray, sandy	4	
Sandstone, with numerous gastropods	1	
Sandstone, massive, slightly cross-bedded, fairly well rounded grains of quartz	4	
Sandstone, calcareous, contains gastropod remains		6
Sandstone, massive, slightly cross-bedded	15	
Sandstone; weathers buff; resistant, in layers 1 inch to 6 inches	1	6

Location G, T. 2 N., R. 97 W.—Continued.

	Ft.	in.
Shale, sandy, and friable sandstone; the sandstone predominates but does not form ledges. This is supposed to be typical Wasatch.		
Total section	1,605	11½
Total shale yielding more than 15 gallons to the ton	41	8

Section near location H, from gas well to mouth of Piceance Creek, T. 1 N., R. 97 W.

	Ft.	in.
Sandstone, coarse, yellowish brown, friable, cross-bedded	169	
Shale, light gray	10	
Sandstone, tan-colored, friable	20	
Sandstone, brown, friable	160	
Shale, light gray, sandy (sample 42; 0.31 gallon)	45	
Shale, gray, thin bedded	12	
Shale, hard, brown, rich, lenticular	1	
Shale, gray	73	
Sandstone, yellowish brown at base; contains vegetable remains	55	
Shale, with few lenses of sandstone, much distorted	40	
Shale, aandy, very lean	5	
Shale, sandy at base	60	
Shale, sandy at top	24	
Shale, hard, brown, rich		3
Shale, sandy	25	
Shale, sandy, thin bedded	2	6
Shale, lean (90 per cent), and hard, rich shale (10 per cent)	1	6
Shale, sandy, thin bedded, gray	3	
Sandstone, massive, yellowish brown, coarse grained	17	
Sandstone, yellowish, thin bedded	12	
Shale and thin beds of rich, hard shale	32	
Shale, sandy, thin bedded	17	
Shale, hard, rich, and thin-bedded shale	3	
Shale, sandy	10	
Shale, hard, brown, rich		1
Shale, sandy, thin bedded	30	
Shale, for the most part barren but including beds as thick as 1 foot which will yield considerable oil	132	
Sandstone, clayey	5	
Shale, hard, brown, lean	3	
Sandstone, clayey, shaly	17	
Shale, sandy (80 per cent), and hard, rich shale (20 per cent)	2	6
Shale, hard, brown (sample 38; 25.2 gallons)	5	11
Shale, slightly sandy	10	
Sandstone, calcareous	3	
Shale, partly rich and partly curly	3	
Shale, top sandy, tan-colored	80	
Shale, hard, brown, rich (90 per cent), and lean shale (10 per cent)	2	

Section near location H, from gas well to mouth of Piceance Creek, T. 1 N., R. 97 W.—Contd.

	Ft.	in.
Shale, thin bedded, carbonaceous, sandy	3	
Shale, curly, lean (75 per cent), and hard, rich shale (25 per cent)	3	4
Shale, sandy	5	
Shale, curly, lean	2	
Shale, drab		6
Sandstone, irregularly bedded		2
Shale, thin bedded, lean	10	
Shale, thin bedded, lean (90 per cent), and hard, rich shale (10 per cent)		6
Shale, thin bedded, sandy	5	
Shale, thin bedded (90 per cent), and hard, rich shale (10 per cent)	1	
Shale, slightly curly, lean	5	
Sandstone, clayey	1	
Shale, thin bedded at base, sandy at top	25	
Shale, hard, rich		6
Shale, sandy	2	
Sandstone, calcareous	5	
Shale, thin bedded, curly	1	
Shale, hard, brown, variable thickness (sample 37; 23.25 gallons)	5	8½
Shale, thin bedded	20	
Shale, curly, and hard, rich shales		10
Shale, brown, thin bedded, lean	3	
Shale, sandy, thin bedded	15	
Shale, thin bedded, curly	1	
Shale, sandy		5
Shale, thin bedded, slightly curly	1	
Shale, hard, brown, rich	2	
Shale, brown, lean		10
Shale, thin bedded, slightly carbonaceous	10	
Shale, hard, rich		6
Shale, black, carbonaceous, lean	2	
Shale, thin bedded, drab	18	
Shale, hard, rich (50 per cent), and lean shale (50 per cent)	2	
Shale, slightly curly (95 per cent), and rich shale (5 per cent)	1	
Shale, sandy	100	
Shale, hard, rich, and lean shale (estimated yield, 30 gallons)	3	
Shale, thin bedded, lean	5	
Shale, massive, rich; weathers bluish	5	
Shale, thin bedded, lean (90 per cent), and rich shale (10 per cent)	52	
Shale, dark brown, rich, and lean shale (50 per cent each)	16	
Shale, hard, dark brown, rich	5	
Shale, drab	2	
Shale, thin bedded, lean	3	
Shale, weathers blue; massive, rich (samples 32, 33, 34, 35, and 36; 14.7 to 40.6 gallons)	5	
Shale, thin bedded, lean	31	
Shale, hard, dark brown, rich	3	
Shale, hard, black, rich	1	
Shale, thin bedded, lean	28	
Shale, hard, dark brown; estimated yield, 15 gallons	1	
Shale, light gray	2	
Shale, curly; will yield oil	1	6

Section near location H, from gas well to mouth of Piceance Creek, T. 1 N., R. 97 W.—Contd.

	Ft.	in.
Shale, dark brown, hard, rich		3
Shale, sandy, carbonaceous	3	4
Shale, curly, papery, and small lenses of solid hydrocarbons	2	
Shale, dark brown, hard, rich		4
Shale, drab	37	
Shale, partly papery, curly, with a few ½-inch beds of hard, dark-brown, rich shale	35	
Shale, curly, papery; will yield oil	40	
Shale, dark brown, thin bedded	3	4
Shale, sandy	1	
Shale, brown, curly, with lenses of sandstone	5	
Sandstone, lenticular (sample 31; 15.5 gallons)		2
Shale, thin bedded	1	2
Shale, light brown, lean		8
Shale, very dark brown, curly, thin bedded		8
Shale, thin bedded, brown		8
Shale, curly	4	4
Shale, curly, papery, will yield oil	20	
Covered, mostly shale	30	
Shale, curly, papery; will yield oil	3	
Covered, probably mostly shale	15	
Shale, dark brown, rich		1
Shale, much of it papery, curly; will yield a small amount of oil	154	
Shale, curly, papery, fairly rich (samples 27, 28, 29, and 30; 8.4 to 12.5 gallons)	15	
Shale, much of it curly and will yield oil	67	
Shale, curly, papery; will yield oil	8	
Shale and clay, tan	48	
Oolite	1	
Shale, sandy at base	40	
Oolite	3	
Sandstone	42	
Sandstone, ripple marked at top, with lenses of oolite	22	
Shale, sandy	5	
Oolite, massive; weathers brown	3	
Sandstone	8	
Sandstone, oolitic at base, thin bedded at top	7	
Oolite	2	
Sandstone	41	
Sandstone, brown, fossiliferous (gastropods)	2	
Sandstone, massive, irregular base, ripple marked on top	5	
Covered, but probably tan-colored shale	83	
Sandstone, resistant and cross-bedded at top, friable near base	27	
Sandstone, light gray to white, coarse	3	
Sandstone, clay, and varicolored lenticular shale	200	
Total section	2,496	6½
Total shale yielding more than 15 gallons to the ton	68	3
Total shale yielding more than 30 gallons to the ton	8	

Location I, north of White River, T. 1 N., R. 96 W.

	Ft.	in.
Sandstone, ripple marked	25	
Sandstone and shale	189	
Sandstone, conglomeratic, friable, yellow	15	
Shale, yellow	58	
Shale, drab	1	
Shale, brown, lean	1	
Shale, drab, with thin beds of rich shale	2	
Shale, thin bedded, curly	1	
Shale, drab	1	
Shale, lean (25 per cent), and rich shale (75 per cent)	1	
Shale, sandy	4	
Shale, dark brown, massive, rich	1	
Sandstone, friable		6
Shale, thin bedded, and lean brown shale	4	
Sandstone, oolitic, tan-colored	1	
Shale, gray, thin bedded	15	
Sandstone, oolitic and conglomeratic	3	
Shale, gray, thin bedded	35	
Shale and sandstone, lean	77	
Sandstone, friable	4	
Shale, sandy	2	
Shale, curly (estimated yield, not more than 10 gallons)	5	
Interval	24	
Sandstone, oolitic, ripple marked	3	
Shale and sandstone, lenticular	167	
Sandstone, oolitic, and oolite	10	
Shale and thin beds of sandstone	85	
Shale, brown, curly	5	
Sandstone, friable, lenticular	10	
Shale, sandy, drab	47	
Shale, thin bedded	3	
Shale, sandy, drab	75	
Total section	874	6
Total shale yielding more than 15 gallons to the ton	1	

Location J, T. 1 N., R. 96 W.

	Ft.	in.
Shale, gray; probably will yield little or no oil	200	
Shale, containing a few thin beds of rich black shale	20	
Shale; contains a large number of rich layers interbedded with sandy shale	20	
Shale, thin bedded; contains a large number of thin beds of rich shale; the whole slightly richer than the unit next above	15	
Shale, hard, dark brown, rich		6
Shale; contains a few thin beds of rich shale	8	
Shale, hard, dark brown, rich		2
Shale, thin bedded, slightly sandy	2	
Shale, hard, dark brown, rich (sample 41; 13.7 gallons)	1	4
Shale lean	2	
Shale, hard, brown, massive (sample 40; 12.5 gallons)	3	8
Shale, interbedded with layers of rich shale; the whole probably lean	6	
Shale, thin bedded, slightly sandy	15	

Location J, T. 1 N., R. 96 W.—Continued.

	Ft.	in.
Shale, hard, dark brown, rich		4
Shale, thin bedded	5	
Shale, hard, dark brown, rich		10
Shale, sandy	5	
Shale, hard, dark brown, rich	1	
Sandstone		8
Shale, hard, dark brown, rich, with some lean layers	3	
Shale, thin bedded, slightly sandy	50	
Shale, hard, dark brown, rich		8
Shale, thin bedded, slightly sandy, containing caverns in places filled with solid hydrocarbon	5	
Shale, sandy	7	
Shale, lean	1	
Shale, hard, dark brown, rich	1	
Shale, thin bedded, slightly sandy	5	
Shale, hard, dark brown, rich	1	
Shale, lean, slightly sandy	2	
Shale, sandy, thin bedded	11	
Shale, sandy; contains a few thin layers of rich shale	5	
Shale, gray, slightly sandy	4	
Shale, hard, dark brown, rich, with lean shale interbedded	1	10
Shale, gray, slightly sandy	8	
Shale, lean		6
Shale, sandy	3	4
Sandstone, tan-colored		4
Shale; probably will yield a small amount of oil		10
Shale, gray	6	
Shale, hard, dark brown, rich	2	
Shale, papery, lean	3	
Shale, sandy		5
Shale, dark brown, rich		½
Shale, lean		7
Shale, rich		8
Shale, gray, slightly sandy	10	
Shale, hard, dark brown, rich		6
Shale, lean	6	
Shale, very lean	1	
Shale, sandy	5	
Shale, dark brown, rich		1
Shale, lean	1	6
Shale, hard, dark brown, rich		3
Shale, lean		10
Shale, dark gray, thin bedded, lean		6
Shale, gray, slightly sandy	5	
Shale, brown to black, thin bedded, rich	3	
Shale, brown to black, thin bedded, probably lean	2	
Shale, sandy, thin bedded	3	6
Shale, dark brown to black, thin bedded, lean	2	10
Shale, dark brown to black, thin bedded to almost papery, lean	1	6
Shale, hard, dark brown, rich		2
Shale, drab, thin bedded, sandy	5	
Sandstone, massive, showing slight ripple marks	3	
Shale, sandy	8	
Sandstone, massive, resistant	2	
Shale, gray, thin bedded	3	
Sandstone		4
Shale, gray, thin bedded	45	

Location J, T. 1 N., R. 96 W.—Continued.

	Ft.	in.
Sandstone, massive, cross-bedded	15	
Shale, gray, thin bedded	5	
Shale, dark gray to black, probably lean.	1	
Shale, gray, thin bedded, with thin beds of sandstone	25	
Shale, hard, dark brown, rich		3
Shale; weathers gray; lean	1	
Shale, gray, thin bedded	12	
Shale, thin bedded, dark brown to black on fresh surface (sample 39; 13.7 gallons)	3	
Shale, hard, brown, probably rich		6
Shale, thin bedded, lean		8
Shale, hard, dark brown, rich		3
Sandstone, with numerous fragments of vegetable remains	2	
Shale, gray, sandy, with thin beds of lean shale	10	
Sandstone, coarse grained, conglomeratic, containing flat pebbles of shale	1	
Shale and sandstone; much of the surface covered	45	
Sandstone, conglomeratic, tan-colored; contains flat pebbles of shale as long as 4 inches and as thick as one-quarter inch	3	
Sandstone, tan-colored, massive, slightly friable, minutely cross-bedded	35	
Shale, drab, sandy	55	
Sandstone	1	
Sandstone and shale, fossiliferous	30	
Sandstone, tan-colored on weathered surface, minutely cross-bedded	2	
Shale, sandy; one fossil leaf was found in this member	5	
Total section	1,166	10½
Total shale yielding more than 15 gallons to the ton	18	

Location K, on north side of Fourteenmile Creek, T. 3 S., R. 95 W.

	Ft.	in.
Sandstone, brown, massive	50	
Shale, light brown	75	
Shale, thin bedded, light brown, lean (sample 44; 6.2 gallons)	64	
Sandstone, shaly	19	
Shale, thin bedded; weathers light gray; probably as rich as the bed from which sample 43 was taken	40	
Sandstone, shaly	17	
Shale, thin bedded; weathers light gray; probably as rich as the bed from which sample 43 was taken	59	
Shale, dark brown but probably not rich		3
Shale, thin bedded, very hard, black	1	5
Shale, brown, hard, probably lean		7
Shale, very dark brown, hard	1	6
Shale, dark brown, containing small lenses of sandstone	1	

(sample 43; 9.4 gallons.)

Location K, on north side of Fourteenmile Creek, T. 3 S., R. 95 W.—Continued.

	Ft.	in.
Sandstone, irregular in thickness		2
Shale, lean (80 per cent), and rich brown shale (20 per cent)	35	
Shale, light brown; weathers white; lean.	7	
Interval, probably mostly shale	40	
Shale, gray	110	
Shale, thin bedded, light colored	10	
Shale, dark drab, thin bedded	28	
Shale, very thin bedded, with thin layers of rich dark-brown shale	1	
Shale, gray, lean; weathers to small plates	5	
Shale, thin bedded, lean	11	
Sandstone, coarse grained, irregular bedded		6
Shale, bluish gray	11	
Sandstone, fine grained		8
Shale, bluish gray; contains vegetable remains	12	
Sandstone, brown, shaly	10	
Shale, gray, with a few thin beds of rich shale	117	
Sandstone, grayish brown		8
Shale, drab, platy; contains stems of wood and pockets of solid hydrocarbon	65	
Sandstone, gray	4	
Shale, gray	17	
Sandstone, brown	1	
Shale, gray	2	
Sandstone, brown	1	
Shale, gray, clayey	77	
Sandstone, coarse, yellow	7	
Shale, drab; contains wood fragments	80	
Sandstone, coarse, angular grains, yellow	2	
Shale, gray	5	
Sandstone, brown, coarse	1	
Shale, light drab	15	
Sandstone, coarse, yellowish brown	3	
Shale, light drab, very clayey	53	
Sandstone, yellowish brown, ripple marked	1	6
Shale, drab, sandy, with three thin beds of brownish sandstone	32	
Sandstone, yellowish brown, upper part oolitic; contains rounded quartzite pebbles	19	
Top of Wasatch formation.		
Total section	1,113	
Total shale yielding more than 15 gallons to the ton	1	6

Location L, on Piceance Creek, T. 4 S., R. 94 W.

	Ft.	in.
Sandstone, brown, massive	150±	
Shale, sandy; weathers light gray	95	
Shale, dark brown, hard; weathers gray; lean	112	
Shale, hard, dark brown, rich		5
Shale, dark brown, hard; weathers gray (probable yield, less than 15 gallons)	11	
Shale, hard, black; weathers bluish (estimated yield, 25 gallons)	2	
Shale, dark brown, hard; weathers gray; lean	40	

Location L, on Piceance Creek, T. 4 S., R. 94 W.—Continued.

	Ft.	in.
Shale, hard, dark brown (estimated yield, 30 gallons)	1	
Shale, dark brown; weathers gray; lean.	168	
Shale, dark brown, rich, and thin-bedded shale	2	
Shale, brown; weathers gray; with a few thin beds of hard, dark-brown, rich shale	38	
Sandstone, shaly; weathers reddish brown	90	
Shale, drab	100	
Sandstone	4	
Shale	18	
Sandstone	3	
Shale, drab, slightly sandy	523	
Shale, bluish drab, with about 5 per cent of beds of sandstone 5 inches thick	102	
Shale, drab, slightly sandy, interbedded with layers of sandstone 1 foot thick	120	
Sandstone, brown, coarse grained	8	
Shale, drab, slightly sandy, with about 8 per cent of sandstone in beds 4 inches thick	60	
Sandstone, brown	10	
Shale, drab, somewhat sandy, interbedded with about 20 per cent of sandstone in beds 8 inches thick	65	
Sandstone, brown	8	
Shale, drab, sandy, with about 40 per cent of sandstone in beds 1 foot thick	45	
Sandstone, gray	15	
Sandstone in beds averaging 6 feet thick, interbedded with gray sandy shale (shale probably 50 per cent of the whole)	200	
Sandstone, massive, brown	12	
Sandstone and gray shale, Wasatch.		
Total section	2,002	5
Total shale yielding more than 15 gallons to the ton	5	5

Location M, on north side of Pole Gulch, T. 4 S., R. 94 W.

	Ft.	in.
Shale, light brown, weathers gray; contains a few thin beds of rich shale	75	
Shale, black, massive; weathers dark blue; rich	1	
Shale, light brown; weathers gray; contains several thin beds of sandstone, also thin beds of rich shale	17	
Shale, dark brown, rich		8
Shale, light brown; weathers gray; will yield a small quantity of oil	25	
Shale, brown (sample 46; 12.5 gallons)	5	2
Shale, gray, lean	5	
Shale, brown, probably not quite as rich as the bed from which sample 46 was taken	4	6
Shale, light brown; will yield a small quantity of oil	5	
Shale, brown, weathers thin bedded, curly (estimated yield, 15 gallons)	2	

Location M, on north side of Pole Gulch, T. 4 S., R. 94 W.—Continued.

	Ft.	in.
Shale, light brown, with beds of rich shale (probable yield less than 10 gallons)	11	
Shale, dark brown; weathers blue	1	1
Shale, very light brown; weathers yellowish gray; will yield very little oil	15+	
Total section	167	5
Total shale yielding more than 15 gallons to the ton	2	9

Location N, on the face of a cliff southwest of Cook's ranch, T. 4 S., R. 94 W.

	Ft.	in.
Top of cliff approximately 1,400 feet above the base of the Green River formation.		
Shale, thin bedded; weathers platy; lean	15	
Shale, dark brown, rich; weathers bluish gray and thin bedded		6
Shale, light brown; weathers yellow; probably will yield a small quantity of oil	3	
Shale and thin sandstone bed	5	
Shale, lean	3	6
Shale, yellowish gray; will yield but little oil	5	
Shale, light brown; weathers to thin laminae (sample 49; 10.5 gallons)	3	
Shale, yellowish gray, probably very lean		7
Shale, dark brown, rich		6
Shale; weathers gray; probably will yield a small quantity of oil	7	
Shale, dark brown, rich (sample 48; 15.5 gallons)	4	
Shale and thin-bedded sandstone; will probably yield a little oil	5	
Shale, brown, lean	2	
Shale, light gray	6	
Shale, dark brown, rich; weathers bluish gray		5
Shale, lean (estimated yield, 10 gallons)	2	
Shale, light brown, very lean	4	
Shale, dark brown, rich		1
Shale		3
Shale, dark brown, rich		1
Sandstone, irregularly bedded		2
Shale, dark brown, rich, containing much pyrite		2
Shale, gray, and thin sandstone	10	
Shale, dark brown, rich; weathers bluish gray		1
Shale, lean	11	
Shale, hard, dark brown; weathers bluish gray; contains a large amount of pyrite	10	
Shale, gray (may yield as much as 10 gallons)	11	
Shale, thin bedded (may yield as much as 15 gallons)		8
Shale, weathers white	16	
Shale; weathers bluish (will not yield more than 10 gallons)		10

Location N, on the face of a cliff southwest of Cook's ranch, T. 4 S., R. 94 W.—Continued.

	Ft.	in.
Shale, dark brown, rich; weathers blue; contains a large amount of pyrite		3
Shale and sandstone	6	
Shale; weathers white		1
Sandstone		3
Shale; weathers white; lean	1	6
Sandstone		3
Shale; weathers white; will yield a little oil	1	8
Shale; weathers bluish; thin bedded (sample 47; 7 gallons)	2	
Shale; will yield a little oil	2	6
Talus slope concealing the lower rocks.		
Total section	141	4
Total shale yielding more than 15 gallons to the ton	15	6

Location O, in Parachute Cliffs north of Morris station, T. 6 S., R. 94 W.

	Ft.	in.
Shale, brown; makes the upper part of the cliff; probably will yield considerable oil but could not be examined	210±	
Shale; weathers thin bedded; black to bluish gray (sample 50; 40.6 gallons)	10	
Shale (probably will yield less than 15 gallons)	25	
Shale, hard, black, rich. Sandstone (excluded from sample). Shale, light brown, very hard. **Shale**, black, hard; appears to be very rich. (sample 51; 28 gallons).	2	
		2
	1	10
		5
Shale; weathers white; thin bedded, slightly carbonaceous; contains a few thin beds of rich shale, also sandstone lenses	40	
Shale, light yellow, thin bedded, sandy	30	
Sanstone, coarse grained	2	
Shale; weathers white; contains some sandy beds	40	
Shale, rich, dark brown		1
Shale, slightly sandy, thin bedded	1	
Shale, rich, dark brown		3
Shale, slightly sandy, gray	1	
Shale, dark brown, rich		8
Shale, lean		6
Shale, mostly gray, partly sandy; contains a few beds of curly shale; the whole is supposed to be very lean	75	
Shale, with some sandstone beds as thick as 2 feet	120	
Sandstone, tan-colored, coarse grained	25	
Shale, dark brown, rich		3
Sandstone (90 per cent) and shale (10 per cent); sandstone coarse grained, cross-bedded, conglomeratic in lower part	25	
Shale (90 per cent) and sandstone (10 per cent); this member contains beds of sandstone as thick as 8 feet; shale is in places slightly carbonaceous	100	

Location O, in Parachute Cliffs north of Morris station, T. 6 S., R. 94 W.—Continued.

	Ft.	in.
Sandstone, light tan-colored to gray, very persistent in thickness	5	
Sandstone (25 per cent) in beds not over 8 inches thick and drab shale (75 per cent)	25	
Oolite (50 per cent) and thin-bedded carbonaceous shale (50 per cent); contains fish scales	2	
Sandstone (10 per cent) and shale (90 per cent); some of the sandstone beds are as much as 5 feet thick and are conglomeratic	60	
Shale, drab; contains a few thin beds of sandstone	60	
Shale (90 per cent), in places thin bedded and slightly carbonaceous, and sandstone, in part ripple marked (10 per cent)	70	
Sandstone (50 per cent) and gray shale, in part clayey (50 per cent); sandstone at top is even bedded and appears persistent; that in the lower part is irregular in thickness	100	
Shale, for the most part gray (75 per cent), and thin-bedded sandstone (25 per cent)	300	
Sandstone and shale; sandstone beds are massive, tan-colored for the most part, and cross-bedded; shale in the lower part of the member is yellow and is similar to Wasatch. At the base of the member is a bed of massive sandstone 10 feet thick, with 15 feet of thin-bedded sandstone above. These beds are irregular in thickness and look like the typical Wasatch	750	
Variegated clays and shales with sandstone lenses at irregular intervals.		
Total section	2,082	2
Total shale yielding more than 15 gallons to the ton	15	11+
Total shale yielding more than 30 gallons to the ton	10+	

Location P, in upper part of Parachute Cliffs, north of Rulison, Colo., T. 6 S., R. 95 W.

	Ft.	in.
Shale, massive, probably will yield considerable oil; forms at this locality impassable cliff	100±	
Shale, light brown (sample 56; 11.2 gallons)	15	
Shale, brown, probably richer than that of the bed above	100	
Shale, dark brown (sample 55; 15.4 gallons)	13	
Shale, probably as rich as that above	20	
Sandstone, shaly	10	
Shale, probably fairly rich in oil	35	
Shale, thin bedded; weathers black; inclined to be curly (to be correlated with the bed from which sample 50 was taken; see above)	6	

Location P, in upper part of Parachute Cliffs, north of Rulison, Colo., T. 6 S., R. 95 W.—Continued.

	Ft.	in.
Shale; weathers yellowish; lean	25	
Shale, dark brown; weathers gray sample 54; 20.7 gallons)	8	
Talus slope.		
Total section	332	
Total shale yielding more than 15 gallons to the ton	82+	
Total shale yielding more than 30 gallons to the ton	6+	

Location Q, in Cathedral Bluffs, about sec. 16, T. 1 S., R. 100 W.

	Ft.	in.
Sandstone, yellow, coarse	10	
Shale, white	25	
Shale, sandy, yellow	185	
Shale, lean	185	
Shale		2
Shale, lean	8	
Shale		1
Shale, barren	1	2
Shale, rich (sample 228; 17 gallons)	1	
Shale (not sampled) (sample 228; 17 gallons)	1	
Sandstone (not sampled) (sample 228; 17 gallons)		1
Shale, thin bedded (sample 228; 17 gallons)	2	2
Shale, lean (not sampled) (sample 228; 17 gallons)	2	8
Shale, thin bedded, rich (sample 228; 17 gallons)	2	
Shale, lean	3	
Sandstone, ferruginous, concretionary		5
Shale, barren	6	
Shale, thin bedded (sample 227; 21 gallons)	7	2
Shale, massive (sample 226; 30 gallons)	5	9
Shale, medium rich	1	
Sandstone		2
Shale, massive, lean		7
Sandstone		1
Shale, thin bedded, lean	1	
Shale (sample 225; 25 gallons)	8	10
Sandstone		1
Shale, probably nearly as good as sample 224	15	
Shale, massive, medium rich (sample 224; 18 gallons)	15	6
Shale, partly massive, partly sandy, partly thin bedded	8	
Shale, lean, with thin beds of rich shale	15	
Interval, covered, probably barren shale	36	
Shale, medium rich	2	
Shale, barren	3	
Shale, thin bedded, like sample 223	2	1
Shale, thin bedded, lean	27	
Shale (sample 223; 21 gallons)	7	2
Shale, thin bedded, like sample 222	15	
Shale, thin bedded, lean	19	
Shale, thin bedded, medium rich	1	10
Shale, thin bedded, mostly lean	23	
Shale, thin bedded (sample 222; 9 gallons)	6	
Shale, lean or barren	11	

Location Q, in Cathedral Bluffs, about sec. 16, T. 1 S., R. 100 W.—Continued.

	Ft.	in.
Shale, thin bedded, about like sample 221	3	6
Shale, thin bedded, not as rich as sample 221	9	6
Shale thin bedded, lean (sample 221; 13 gallons)	12	9
Talus covering shale at base of section, probably for most part lean.		
Total section	689	9
Total shale yielding more than 15 gallons to the ton	63	
Total shale yielding more than 30 gallons to the ton	5	9

Location R, a quarter of a mile below junction of Middle Duck and Big Duck creeks, about sec. 19, T. 1 S., R. 99 W.

	Ft.	in.
Upper slopes covered. Farther up canyon, at forks of creeks, a massive rich bed is partly exposed in the beds of the creeks.]		
Shale, chiefly lean	30	
Shale, thin bedded, medium rich	12	
Sandstone, yellowish, concretionary	2	4
Shale, thin bedded, lean to barren	10	
Shale, thin bedded, medium rich	6	4
Shale, yellowish, sandy	2	10
Shale, massive, medium rich	4	2
Shale, thin bedded, lean	8	
Shale, massive, lean to medium rich	9	8
Shale, massive, medium (sample 229; 25 gallons)	9	4
Shale, thin bedded, medium rich to lean	10	
Total section	104	8
Total shale yielding more than 15 gallons to the ton	9	4

Location S, about sec. 21, T. 2 S., R. 100 W.

	Ft.	in.
Shale, thin bedded, barren	20	
Shale, rich		2
Shale, lean or barren, with a few thin sandstone beds and probably a few streaks of rich oil shale	242	
Shale, thin bedded, medium rich	11	
Shale (sample 244; 25 gallons)	8	7
Sandstone		2
Shale, barren, yellow	3	
Shale (sample 243; 26 gallons)	4	10
Shale, lean, massive and thin bedded	16	6
Shale (sample 242; 28 gallons)	1	11
Shale, lean	3	
Shale, massive (sample 241; 30 gallons)	3	7
Shale, lean, with thin rich beds	33	
Shale, thin bedded, lean	22	
Shale, thin bedded (sample 240; 22 gallons)	5	6

Location S, about sec. 21, T. 2 S., R. 100 W.—Continued.

	Ft.	in.
Sandstone, yellow		2
Shale, lean and barren, thin bedded, with thin rich streaks	24	
Shale, massive, rich	2	8
Shale, thin bedded, medium rich?	1	
Shale, yellowish, sandy, massive, barren	1	
Shale, thin bedded, medium rich?	1	10
(sample 239; 21 gallons)		
Shale, barren	1	
Shale, thin bedded, medium rich to rich	1	
Shale, barren, sandy	1	
Shale, massive (sample 238; 31 gallons)	4	6
Shale, thin bedded (sample 237; 11 gallons)	6	10
Shale, barren	27	6
Shale, thin bedded (sample 236; 18 gallons)	7	9
Shale, thin bedded, barren	12	
Shale, massive, rich	1	
Shale, lean and barren	43	
Shale, medium rich		8
Shale, barren	5	
Shale, thin bedded, medium rich		10
Shale, barren	5	
Shale, thin bedded, medium rich	2	5
Shale, barren, yellow	7	
Shale, like sample 235	1	4
Shale, thin bedded, lean or barren, with a few sandstone lentils	28	
Shale, massive (sample 235; 34 gallons)	2	4
Shale, lean and barren	14	
Shale, thin bedded, medium rich	2	8
Shale, barren	4	
Shale, thin bedded, medium rich	1	4
Shale, barren, gray	6	8
Shale, thin bedded, lean and barren	7	
Shale, thin bedded (sample 234; 23 gallons)	6	10
Shale, barren, and sandstone, yellow	1	2
Shale, thin bedded (sample 233; 20 gallons)	6	7
Shale, lean and barren	8	6
Shale, thin bedded, lean or medium rich	2	
Sandstone, yellowish		5
Shale, thin bedded, medium rich		9
Shale, thin bedded, interbedded lean and barren	77	
Shale, lean, with rich beds	1	2
Shale, lean or barren	20	
Shale, lean, gray, with a few very rich beds	2	6
Shale, yellowish, sandy	4	
Shale, gray, barren, with a few thin rich beds	38	
Shale, thin bedded, lean	2	
Shale, gray, barren	53	
Sandstone, massive, yellow, with interbedded thin gray shale and sandstone (probably top of Wasatch formation)	68	

Location S, about sec. 21, T. 2 S., R. 100 W.—Continued.

	Ft.	in.
Shale, gray, with sandstone lenses	40	
Shale, brownish, thin bedded, with thin sandstone layers	10	
Shale, brownish, thin bedded (sample 232; 20 gallons)		
Shale, brownish, thin bedded, with thin sandstone layers	6	
Shale, brownish, thin bedded (sample 231; 12 gallons)	4	
Shale, brownish, thin bedded, with thin sandstone layers	13	
Shale, brownish, thin bedded (sample 230; 22 gallons)	5	3
Shale, thin bedded, apparently oil shale; partly burned out	20	
Shale, gray, platy, with interbedded sandstone	396	
Sandstone, massive, yellow; weathers brown	8	
Shale, greenish and gray	35	
Sandstone, massive, yellow	5	
Shale, gray, and gray and yellow sandstone	195	
Sandstone, massive, yellow	10	
Shale, greenish gray; some soft sandstone	25	
Sandstone, massive, gray; weathers yellow	12	
Shale, gray, and greenish sandstone, thin bedded	75	
Sandstone, massive, yellow, with intercalated beds of soft sandstone and shale	58	
Shale and sandstone, thin bedded, greenish	46	
Total section	1,914	6
Total shale yielding more than 15 gallons to the ton	91	9
Total shale yielding more than 30 gallons to the ton	10	5

Location T, south of Little Tommies Draw, sec. 14, T. 3 S., R. 100 W.

	Ft.	in.
Sandstone, yellow	5	
Shale, lean and barren	155	
Shale, thin bedded, medium rich	1	6
Shale, lean and barren	65	
Shale, thin bedded, medium rich	2	6
Shale, lean	9	
Shale, thin bedded, medium rich	4	
Shale, lean and barren	55	
Shale, thin bedded, rich	3	1
Shale, yellow, barren (not sampled)	1	10
Shale, massive	1	2
(sample 253; 22 gallons).		
Shale, badly weathered; may be rich	15	
Shale, thin bedded and massive (sample 252; 22 gallons)	8	6
Shale, thin bedded and massive (sample 251; 26 gallons)	7	11

Location T, south of Little Tommies Draw, sec. 14, T. 3 S., R. 100 W.—Continued.

	Ft.	in.
Shale, yellow, barren	1	8
Shale, thin bedded (sample 250; 27 gallons)	7	2
Shale, thin bedded, lean	6	
Shale, yellow, barren	6	
Shale, thin bedded, lean	9	
Shale, massive, rich	1	8
Shale, thin bedded, lean or barren	4	4
Shale, thin bedded, medium rich	4	
Covered	20	
Shale, yellow, barren	2	3
Shale, thin bedded, lean, with several thin rich beds	3	
Shale, lean, with thin rich beds	22	
Shale, thin bedded, lean, with thin rich beds	3	6
Covered, probably mostly lean and barren shale	105	
Shale, yellow, barren	3	
Shale, thin bedded, lean	3	6
Shale, massive, rich		6
Shale, thin bedded, lean	5	4
Shale, yellow, barren	5	
Shale, thin bedded, medium rich	2	10
Shale, thin bedded, yellow, barren	9	
Shale, medium rich	2	
Shale, barren (not sampled) (sample 249; 22 gallons)	1	10
Shale, thin bedded	5	
Shale, thin bedded, partly yellow, lean and barren	25	
Shale, thin bedded, rich	1	6
Sandstone, yellow		6
Shale, thin bedded, lean	4	8
Shale, massive, yellow, barren	4	6
Shale, thin bedded, lean and rich (sample 248; 23 gallons)	3	7
Shale, massive, medium rich	2	
Shale, massive, yellow barren	7	
Shale, thin bedded, medium rich	1	8
Shale, massive, yellow, barren	8	
Shale, thin bedded, lean	10	
Shale, thin bedded (sample 247; 22 gallons)	8	9
Shale, sandy, barren	1	6
Shale, massive (sample 246 A; 24 gallons)	5	2
Shale, massive, yellow, barren	15	
Covered	215	
Sandstone, massive, yellow, with some thin sandstone, and shale (probably top of Wasatch formation)	75	
Covered	325	
Shale, thin bedded, drab, with some yellow sandstone	110	
Sandstone, massive, yellow	15	
Shale, thin bedded, and sandstone (sample 246; 10 gallons from 5 feet at base)	90	
Sandstone, yellow, drab shale, and yellow oolite, with 6 inches of coal and pelecypod-bearing beds	75	

Location T, south of Little Tommies Draw, sec. 14, T. 3 S., R. 100 W.—Continued.

	Ft.	in.
Shale, thin bedded, drab, and brown and yellow sandstone (sample 245; 7 gallons from 3 feet near base)	80	
Sandstone, yellow, with drab shale	60	
Sandstone and shale, soft and thin bedded, with some beds of massive yellow sandstone	36	
Coal		10
Shale, drab, with pelecypods (*Unio*)	7	
Coal	1	
Shale, drab	1	6
Coal	1	2
Sandstone and shale, mostly yellowish drab	95	
Sandstone, massive, yellow	20	
Sandstone and shale, soft	52	
Sandstone, massive, yellow	5	
Shale and sandstone, mostly greenish gray	78	
Sandstone and shale, soft, yellow	13	
Shale and soft sandstone, mostly grayish green	90	
Sandstone, massive, yellow	9	
Sandstone and shale, soft, yellow	9	
Sandstone, massive, soft, yellow	4	
Shale, mostly greenish gray, some purple and drab	43	
Sandstone, massive; weathers olive-brown	15	
Sandstone, massive, soft, white	8	
Shale, grayish green, with soft sandstones	34	
Shale, sandy, red	4	
Sandstone, massive, greenish on fresh surface; weathers olive-brown	3	
Shale, drab and gray-green, with soft sandstones	40	
Sandstone, massive, white and light gray (Mesaverde)	50	
Total section	2,331	5
Total shale yielding more than 15 gallons to the ton	73	
Total shale yielding more than 30 gallons to the ton	10	9

Location U, on Black Sulphur Creek, about sec. 4, T. 4 S., R. 99 W.

	Ft.	in.
Shale, lean, with several thin beds of rich shale	40	
Shale, medium rich	2	4
Covered, mostly lean, with some thin rich beds	48	6
Shale, medium rich	3	
Covered, mostly lean, with three thin rich beds	9	
Shale, medium rich	1	11
Shale, sandy, yellow (not sampled) (sample 259; 24 gallons)		11
Shale, medium rich	6	
Shale, massive (sample 258; 18 gallons)		4

Location U, on Black Sulphur Creek, about sec. 4, T. 4 S., R. 99 W.—Continued.

	Ft.	in.
Sandstone, yellow		7
Shale, yellow, barren	4	6
Shale, thin bedded, mostly lean	5	
Shale, mostly thin bedded (sample 257; 34 gallons)	10	9
Shale, massive and thin bedded	9	9
Shale, yellow, barren (not sampled)	1	7
Shale, massive	2	8
(sample 256; 27 gallons).		
Shale, massive and thin bedded (sample 255; 26 gallons)	7	5
Sandstone, yellow		10
Shale, massive (sample 254; 31 gallons)	6	2
Talus	40	
Total section	204	3
Total shale yielding more than 15 gallons to the ton	48	
Total shale yielding more than 30 gallons to the ton	16	11

Location V, on east side of ridge between East and West forks of Lake Creek, sec. 15, T. 4 S., R. 100 W.

	Ft.	in.
Covered to top of hill.		
Shale, mostly lean or barren	100	
Shale, massive, lean to medium; weathers yellow (sample 270; 16 gallons)	4	2
Sandstone, yellow		8
Shale, lean, thin bedded	5	
Shale, thin bedded (sample 269; 23 gallons)	8	8
Shale, massive; mostly weathers yellow (sample 268; 22 gallons)	4	3
Shale, massive, lean	11	
Shale; part weathers bluish and massive, badly weathered (sample 267; 25 gallons)	4	4
Shale, massive, lean, brown on fresh surfaces; weathers yellow	13	
Sandstone, yellow, concretionary	1	2
Shale, massive, medium rich; weathers partly blue	2	3
Shale, massive, lean; weathers yellow	12	
Sandstone, yellow		4
Shale, mostly yellow and barren	25	
Shale, thin bedded, medium rich; weathers partly bluish	2	
Shale; few rich streaks	25	
Shale, thin bedded, barren, but with numerous rich streaks	5	6
Shale, yellow, barren	3	
Shale, thin bedded, lean and barren	25	
Shale, massive, rich; weathers blue	1	
Shale, lean, thin bedded	5	
Shale, massive, rich; weathers blue	1	6
Shale, barren, yellow	4	6
Shale, thin bedded; weathers bluish in streaks (sample 266; 34 gallons)	3	2
Shale, barren	18	

Location V, on east side of ridge between East and West forks of Lake Creek, sec. 15, T. 4 S., R. 100 W.—Continued.

	Ft.	in.
Shale, massive, bluish, rich		8
Shale, lean and barren, thin bedded	22	
Shale, barren, with numerous rich bluish streaks	8	
Shale, massive, rich		6
Shale, massive, lean and barren	9	
Shale, bluish, massive, rich		6
Shale, lean and barren; some medium-rich bluish streaks	92	
	92	
Shale, thin bedded, lean to medium rich	2	
Shale, thin bedded, lean	13	6
Shale, thin bedded, medium rich	1	6
Shale, massive, barren	1	
Shale, thin bedded, medium rich	1	4
Shale, yellow, barren	3	
Shale, thin bedded (sample 265; 30 gallons)	3	9
Shale, lean and barren	10	
Shale, thin bedded (sample 264; 23 gallons)	3	4
Shale, thin bedded, barren	14	
Shale, massive; weathers blue (sample 263; 29 gallons)	4	10
Shale, sandy, yellow, barren	1	6
Shale, thin bedded, lean, some rich streaks; weathers white	8	
Shale, massive; weathers blue (sample 262; 25 gallons)	3	2
Shale, thin bedded, lean and barren	28	
Sandstone, reddish		2
Shale, thin bedded, lean, with a few thin rich beds	11	
	11	
Sandstone, yellow		2
Shale, barren, with some rich streaks	16	6
Shale, thin bedded, medium rich	1	
Shale, thin bedded, barren	38	
Shale, barren, and yellow oolite	8	
Shale, barren	16	
Limestone, white, partly oolite	1	6
Shale, barren	39	
Shale; slope mostly covered with outcropping ledges of yellow shales, oolite, etc	62	
Covered slope	170	
Sandstones, yellow, massive, with interbedded soft sandstone and sandy shale	40	
Shales, partly petroliferous, partly dark clay shales, with interbedded thin sandstone and oolite (probably top of Wasatch formation) (sample 261, from bed 3 feet thick 65 feet above base, 22 gallons; sample 260, from bed 1 foot 6 inches thick 75 feet above base, 24 gallons)	105	
Sandstone, massive, yellow	12	
Shales, dark	50	
Covered	100	
Total section	1,185	11
Total shale yielding more than 15 gallons to the ton	51	11
Total shale yielding more than 30 gallons to the ton	6	11

Location W, at head of Brush Creek, sec. 31, T. 4 S., R. 99 W.

	Ft.	in.
Covered, mostly barren shale, with some thin rich beds	400	
Shale, thin bedded, black, rich		10
Shale, lean	27	
Shale, thin bedded, light colored, slightly leaner than sample 281	10	
Shale, thin bedded (sample 281; 9 gallons)	4	10
Shale, lean	2	8
Shale, thin bedded (sample 280; 12 gallons)	7	6
Shale, thin bedded, mostly lean or barren	36	
Shale, thin bedded, rich; weathers blue	1	10
Shale, thin bedded, lean or barren, with thin beds of rich shale	47	
Shale, thin bedded, rich	2	6
Sandstone	1	
Shale, thin bedded, lean	24	
Shale, thin bedded, rich		8
Shale, lean	10	
Shale, thin bedded, with several thin beds of sandstone (sample 279; 13 gallons)	6	
Sandstone		3
Shale, lean	6	
Sandstone		5
Shale, lean	1	6
Shale, thin bedded, rich	2	6
Shale, medium to lean	5	
Sandstone		7
Shale, lean	3	4
Shale, thin bedded, brown (sample 278; 30 gallons)	4	
Shale, thin bedded, black (sample 278; 30 gallons)	4	6
Shale, thin bedded, black (sample 277; 23 gallons)	4	
Shale, lean (not sampled) (sample 277; 23 gallons)	2	
Shale, thin bedded, black (sample 277; 23 gallons)	1	8
Shale, lean	2	6
Shale, thin bedded, black (sample 276; 20 gallons)	2	6
Sandstone (not sampled) (sample 276; 20 gallons)		1
Shale, thin bedded, black (sample 276; 20 gallons)	2	10
Sandstone (not sampled) (sample 276; 20 gallons)		½
Shale, thin bedded, black (sample 276; 20 gallons)		5
Shale, medium	3	
Shale, thin bedded, black, rich		11
Sandstone		½
Shale, lean	2	3
Shale, thin bedded, black (sample 275; 22 gallons)		8
Shale, thin bedded, lean (sample 275; 22 gallons)		10
Shale, massive; weathers blue (sample 275; 22 gallons)	5	
Shale, lean, with thin rich streaks	19	

Location W, at head of Brush Creek, sec. 31, T. 4 S., R. 99 W.—Continued.

	Ft.	in.
Sandstone	1	6
Shale, massive, rich, weathers blue	1	3
Covered, mostly lean shale	36	
Sandstone, gray		½
Shale, thin bedded, dark (sample 274; 6 gallons)	3	
Sandstone, yellow, lenticular (not sampled) (sample 274; 6 gallons)		3
Shale, thin bedded, dark (sample 274; 6 gallons)	6	3
Sandstone, yellow (not sampled) (sample 274; 6 gallons)		5
Shale, thin bedded, dark (sample 274; 6 gallons)		6
Shale, thin bedded, lean	3	
Shale, thin bedded, black (sample 273; 23 gallons)	4	
Shale, massive, black (sample 273; 23 gallons)	1	4
Shale, lean	5	
Shale, thin bedded, black, medium rich	1	2
Shale, thin bedded, lean		10
Shale, thin bedded, black, rich		10
Shale, thin bedded, medium rich	10	
Covered, probably lean shale	8	
Shale, thin bedded, black (sample 272; 20 gallons)	2	
Shale, lean (not sampled) (sample 272; 20 gallons)	1	8
Shale, thin bedded, black (sample 272; 20 gallons)	2	4
Shale, massive, black (sample 272; 20 gallons)	1	2
Shale, lean	5	4
Shale; weathers blue (sample 271; 24 gallons)	3	6
Talus, probably mostly lean or barren shale	75	
Total section	822	8½
Total shale yielding more than 15 gallons to the ton	51	3
Total shale yielding more than 30 gallons to the ton	8	6

Location X, near head of Carr Creek, sec. 9, T. 5 S., R. 100 W.

	Ft.	in.
Shale, thin bedded, mostly lean	70	
Shale, thin bedded; averages about like sample 287	32	
Shale, thin bedded (sample 287; 12 gallons)	8	4
Shale, thin bedded, lean, yellow	3	
Shale, thin bedded (sample 286; 9 gallons)	6	8
Shale, massive, medium rich; weathers blue	2	2
Shale, massive, sandy, yellow	5	6
Shale, thin bedded, medium rich	2	
Shale, thin bedded, lean	4	
Shale, thin bedded, medium rich	1	4
Shale, thin bedded, lean	36	
Sandstone, brown		2
Shale, thin bedded, lean	4	
Sandstone, yellow		5
Shale, thin bedded, lean and barren	34	
Shale, thin bedded, medium rich	1	6
Shale, yellow, barren	1	

Location X, near head of Carr Creek, sec. 9, T. 5 S., R. 100 W.—Continued.

	Ft.	in.
Shale, thin bedded, medium rich	1	10
Shale, thin bedded, lean and barren	19	
Shale, thin bedded, lean to medium; weathers blue in streaks (sample 285; 22 gallons)	10	
Sandstone, reddish brown		7
Shale, thin bedded, partly yellow, lean	6	
Shale, thin bedded; weathers blue (sample 284; 44 gallons)	6	2
Shale, thin bedded, barren	1	6
Shale, thin bedded; weathers blue in part	4	6
Sandstone (not sampled)		1
Shale, thin bedded (sample 283; 27 gallons)		9
Shale, mostly thin bedded, lean	7	
Shale, massive; weathers blue (sample 282; 26 gallons)	5	8
Shale, massive; weathers yellow; not as rich as sample 282	5	4
Shale, massive, yellow, barren	7	
Shale, massive, medium rich	1	2
Shale, yellow, barren	1	6
Shale, massive, medium rich; weathers partly blue, partly yellow	1	8
Shale, massive, barren; weathers yellow	4	6
Sandstone, yellow	1	3
Shale, massive, rich; weathers blue	1	
Total section	298	7
Total shale yielding more than 15 gallons to the ton	45	1
Total shale yielding more than 30 gallons to the ton	6	2

Location Y, near head of Little Salt Wash, about sec. 21, T. 6 S., R. 100 W.

	Ft.	in.
Covered to top of ridge	30±	
Shale, covered, but with some very rich shale	8	
Shale, lean	12	
Shale, massive, rich		8
Shale, lean	9	
Shale, thin bedded	1	8
Shale, massive (sample 291; 17 gallons)	1	8
Shale, thin bedded	1	7
Shale, thin bedded, lean	16	
Shale, massive, rich	1	6
Covered	27	
Shale, massive, rich, much twisted	2	
Shale, thin bedded, medium rich	3	
Shale, poorly exposed	23	
Shale, massive, better than sample 288	7	
Shale, lean to medium rich	7	
Shale, massive, rich	1	6
Shale, lean to medium rich	40	
Shale, like sample 288	4	8
Shale, thin bedded, lean	8	
Shale, thin bedded (sample 290; 13 gallons)	4	
Shale, thin bedded, lean	16	
Shale, thin bedded, medium rich	1	
Covered	130	

Location Y, near head of Little Salt Wash, about sec. 21, T. 6 S., R. 100 W.—Continued.

	Ft.	in.
Shale, thin bedded, lean	8	
Shale, thin bedded, rich		10
Shale, thin bedded, lean	18	
Shale, thin bedded, medium rich	1	
Shale, thin bedded, lean to medium rich	10	
Shale, thin bedded (sample 289; 32 gallons)	5	
Shale, thin bedded (sample 288; 18 gallons)	5	
Shale, hard, massive, lean	6	
Talus	100±	
Total section	510±	
Total shale yielding more than 15 gallons to the ton	34	1
Total shale yielding more than 30 gallons to the ton	5	

Location Z, along the trail at Ollis ranch, about sec. 16, T. 6 S., R. 99 W.

	Ft.	in.
Covered to top of ridge; mostly lean shale	200+	
Shale, massive, medium rich	18	
Shale, massive, rich	1	6
Shale, massive, lean	3	
Shale, massive, rich	2	
Shale, massive, medium rich	10	
Shale, massive	2	2
Shale, lean (not sampled) (sample 301; 13 gallons)		4
Shale, massive	4	
Shale, medium rich	7	
Shale, thin bedded (sample 300; 17 gallons)	5	3
Shale, thin bedded, medium to lean	9	
Shale, thin bedded		6
Sandstone (not sampled) (sample 299; 11 gallons)		1
Shale, thin bedded	3	1
Shale, lean, with several rich beds	71	
Shale, hard, medium rich	1	6
Shale, lean	23	
Shale, thin bedded, rich	1	5
Shale, lean to barren	11	6
Shale, thin bedded	2	
Shale, lean to barren (not sampled)	2	
Sandstone (not sampled) (sample 298; 21 gallons)		2
Shale, thin bedded		5
Sandstone, yellow (not sampled)		6
Shale, thin bedded	3	
Shale, medium to lean; weathers yellow (sample 297; 17 gallons)	7	4
Sandstone, yellow, with fossil insects		10
Shale, yellow, barren to lean	9	6
Shale, thin bedded	1	
Shale, yellow, barren (not sampled) (sample 296; 34 gallons)		8
Shale, thin bedded, medium rich		7
Sandstone		1
Shale, massive and thin bedded; weathers blue in streaks (sample 295; 24 gallons)	6	

Location Z, along the trail at Ollis ranch, about sec. 16, T. 6 S., R. 99 W.—Continued.

	Ft.	in.
Shale, lean to barren	5	2
Shale, thin bedded, with massive blue layers (sample 294; 21 gallons)	4	5
Total section	421+	
Total shale yielding more than 15 gallons to the ton	37	11
Total shale yielding more than 30 gallons to the ton	4	7

Location AA, along Newton's trail, about sec. 3, T. 6 S., R. 98 W.

	Ft.	in.
Shale, mostly barren, yellow, to top of ridge	150	
Shale, hard (estimated yield, 20 gallons)	2	
Shale, barren	5	
Shale, hard	2	
Shale, barren	3	
Shale, hard; weathers blue (estimated yield, 25 gallons)	3	
Shale, thin bedded, lean	3	
Shale, hard, massive (estimated yield, 20 gallons)	25	
Shale, thin bedded (sample 309; 18 gallons)	8	11
Shale, mostly thin, barren	27	
Shale, hard, rich; weathers blue (estimated yield, 30 gallons)	1	3
Shale, thin bedded, barren	8	
Shale, rich; weathers blue (estimated yield, 30 gallons)	1	3
Shale, lean	6	6
Shale, hard, medium rich	1	6
Shale, hard, lean	3	
Shale, hard; weathers blue (sample 308; 37 gallons)	2	9
Shale, massive (estimated yield, 15 gallons)	3	
Shale, thin bedded, barren	4	
Shale, medium (estimated yield, 20 gallons)	5	6
Shale, rich; weathers blue (estimated yield, 30 gallons)	2	6
Shale, sandy, barren	4	6
Shale, rich		2
Shale, barren		6
Shale, hard, rich (estimated yield, 30 gallons)	2	6
Shale, hard, medium rich (estimated yield, 15 to 20 gallons)	11	
Shale, hard, rich; weathers blue		10
Shale, thin bedded, and massive, medium rich to lean	28	
Shale, hard, rich (estimated yield, 25 gallons)	2	
Shale, thin bedded, barren	3	
Shale, hard, massive (sample 307; 18 gallons)	1	10
Shale, hard (sample 307; 18 gallons)	1	
Sandstone, irregular	2	

Location AA, along Newton's trail, about sec. 3, T. 6 S., R. 98 W.—Continued.

	Ft.	in.
Shale, lean to barren	10	
Shale, hard (estimated yield, 15 gallons)	2	
Shale, lean to barren	8	
Shale, hard to medium (estimated yield, 15 gallons)	2	
Shale, lean	4	
Shale, hard (estimated yield, 15 gallons)		6
Shale, thin bedded, lean (estimated yield, 5 gallons)	4	6
Shale, hard (estimated yield, 20 gallons)	1	6
Shale, hard, lean to medium rich (estimated yield, 10 gallons)	5	
Shale, thin bedded, medium rich (sample 306; 21 gallons)	4	
Shale, thin bedded, rich (sample 306; 21 gallons)		10
Shale, thin bedded, lean	12	
Shale, thin bedded, rich (estimated yield, 25 gallons)	2	6
Shale, lean to medium rich	4	
Sandstone		2
Shale, thin bedded, lean		6
Sandstone		6
Shale, hard; weathers blue (estimated yield, 25 gallons)		10
Shale, hard, medium rich (estimated yield, 20 gallons)	2	
Shale, hard; weathers blue (estimated yield, 25 gallons)	1	8
Shale, lean	4	
Shale, rich; weathers blue (estimated yield, 25 gallons)	1	6
Shale, lean	2	
Sandstone		5
Shale, lean	3	6
Shale, thin bedded, rich (estimated yield, 30 gallons)	1	8
Shale, thin bedded, lean	1	8
Shale, thin bedded, rich (estimated yield, 25 gallons)	1	
Shale, lean		6
Sandstone		1
Shale, thin bedded, rich (estimated yield, 30 gallons)	1	
Shale, lean	1	2
Shale; weathers blue (sample 305; 45 gallons)	8	1
Shale, lean	1	11
Shale, hard, rich; weathers blue (estimated yield, 35 gallons)	1	5
Shale, lean	3	5
Shale, hard, thin bedded; weathers blue (estimated yield, 35 gallons)	4	6
Shale, massive, medium rich (estimated yield, 20 gallons)	2	10
Shale, lean; weathers yellow	3	
Shale, dark, rich	1	
Shale, lean	3	
Shale, massive, rich (estimated yield, 30 gallons)	6	

Location AA, along Newton's trail, about sec. 3, T. 6 S., R. 98 W.—Continued.

	Ft.	in.
Shale, massive, medium	20	
Shale, thin bedded, rich, like sample 304	2	6
Shale, lean	5	
Sandstone		5
Shale, massive, rich		10
Sandstone	1	5
Shale, lean, mostly covered	33	
Shale, thin bedded, rich (sample 304; 38 gallons)	2	8
Shale, medium rich to rich	5	
Sandstone		2
Shale, hard, lean to medium rich	20	6
Shale, hard (sample 303; 25 gallons)	4	2
Shale, lean	1	9
Shale, hard (sample 302; 23 gallons)	5	2
Talus to creek with some medium shale and thin rich beds	300±	
Total section	549	6
Total shale yielding more than 15 gallons to the ton	143	11
Total shale yielding more than 30 gallons to the ton	35	5

Location BB, north of Dry Fork Creek, above the sawmill and shale camp, T. 7 S., R. 100 W.

	Ft.	in.
Shale, thin bedded, gray and dark (sample 315; 25 gallons)	8	
Shale, light	8	
Shale, thin bedded, black (sample 314; 32 gallons)	5	
Shale, light to brown (sample 313; 23 gallons)	15	
Shale, light	3	
Shale, blue-gray (sample 312; 15 gallons)	1	
Shale, gray		10
Shale, dark brown	1	
Sandstone with thin shale beds	1	6
Shale, gray to dark (sample 311; 22 gallons)	2	6
Sandstone, green, gray, and red	1	4
Shale (sample 310; 14 gallons)	1	5
Total section	48	7
Total shale yielding more than 15 gallons to the ton	36	4
Total shale yielding more than 30 gallons to the ton	5	

Location CC, north side of Dry Fork Creek, above Armstrong sawmill, west of De Beque, about sec. 27, T. 7 S., R. 100 W.

	Ft.	in.
Shale to top of ridge (barometer 8,100). This series is about 40 per cent shale that will test probably more than 20 gallons. Upper 75 feet contains several beds 3 feet or more thick of hard black shale that may yield 30 gallons to the ton	480	
Shale (estimated yield, 20 to 30 gallons)	3	
Shale (estimated yield, 15 to 20 gallons)	12	
Shale, thin bedded, rich (sample 188; 38 gallons)	5	

Location CC, north side of Dry Fork Creek, above Armstrong sawmill, west of De Beque, about sec. 27, T. 7 S., R. 100 W.—Continued.

	Ft.	in.
Shale, moderate	1	2
Shale, rich (sample 189; 22 gallons)		5
Shale, lean		10
Shale, rich, papery	1	1
Shale, lean (estimated yield, 10 gallons)		9
Shale, rich (estimated yield, 40 gallons)		5
Shale, lean (estimated yield, 10 to 15 gallons)	1	8
Shale (estimated yield, 40 gallons)		10
Shale, lean		11
Shale (sample 187; 21 gallons)	3	8
Shale (estimated yield 10 to 15 gallons)	3	
Shale, thin bedded (estimated yield, 40 gallons)		5
Shale (estimated yield, 10 gallons)	3	7
Sandstone, brown		4
Shale, papery (estimated yield 30 gallons)	1	2
Shale, lean to barren	1	2
Shale, papery (estimated yield, 30 gallons)	1	1
Shale (estimated yield, 10 gallons)	1	9
Sandstone, slightly asphaltic	1	
Shale, hard (estimated yield, 20 gallons)	3	
Total section	528	8
Total shale yielding more than 15 gallons to the ton	34	6+
Total shale yielding more than 30 gallons to the ton	9	4+

Location DD, south side of Dry Fork ridge, east of Oil Shale Mining Co.'s camp.

	Ft.	in.
Shale, mostly barren to top of hill	75	
Shale, solid, black (sample 320; 18 gallons)	2	4
Shale, thin bedded, mostly lean	115	
Shale, lean	5	
Shale, thin bedded (sample 319; 15 gallons)	3	7
Shale, brown, barren	5	
Shale, medium rich	1	4
Shale, lean	3	4
Shale (sample 318; 12 gallons)	2	
Shale, thin bedded, mostly barren	110	
Shale, thin bedded, rich (sample 317; 38 gallons)	5	10
Shale, lean and barren	3	1
Shale, medium rich	2	8
Shale, barren	2	
Shale, medium rich	1	
Shale, lean and barren	10	
Shale, barren and lean	5	
Shale, lean	30	
Sandstone		8
Shale, lean, and thin sandstone	2	8
Sandstone	35	
Total section	420	6
Total shale yielding more than 15 gallons to the ton	16	9
Total shale yielding more than 30 gallons to the ton	5	10

Location EE, at forks of Parachute Creek, about 10 miles north of Grand Valley, about sec. 36, T. 5 S., R. 96 W.

	Ft.	in.
Interval to top (estimated)	150±	
Shale (estimated average yield, 15 gallons)	125	
Shale (estimated average yield, 30 gallons)	75	
Shale, rich, hard (sample 193, 5 feet near middle of bed; 42 gallons)	25	
Shale (average nearly as good as sample 192; probably 30 gallons)	30	
Covered and lean shale	86	
Shale (estimated yield, 30 gallons)	45	
Shale (as good or better than sample 192)	4	6
Shale, sandy, lean	6	
Shale (estimated yield, 25 gallons)	4	
Shale (nearly as good as sample 192)	5	
Shale, medium	15	
Shale, hard, blue (like sample 192)	3	
Shale, medium	9	
Shale, hard, blue (like sample 192)	2	
Shale, medium	9	
Shale, hard, blue (sample 192; 36 gallons)	2	6
Interval, probably 40 per cent shale in beds 3 feet or more thick which will test 25 gallons or more to the ton	175	
Shale (like sample 191)	2	
Shale, medium rich	5	6
Shale (like sample 191)	3	
Shale, medium rich	11	
Shale (like sample 191)	2	
Shale, lean	6	6
Shale, hard, blue (sample 191; 19 gallons)	5	4
Shale, sandy, yellow	5	
Shale (estimated yield, 25 gallons)	18	
Shale, slightly less rich than 190	12	
Shale, hard (sample 190; 18 gallons)	6	4
Sandstone		3
Shale, lean.		
Total section	847	11
Total shale yielding more than 15 gallons to the ton	386	2
Total shale yielding more than 30 gallons to the ton	72	

Location FF, along Mount Logan trail, sec. 26, T. 7 S., R. 97 W.

[Measured by E. G. Woodruff.]

	Ft.	in.
Soil on plateau overlying very sandy brown shale.		
Shale, bituminous, "curly"	11	
Shale, very light brown	130	
Shale, bituminous, "curly"	2	3
Shale, moderately bituminous; bitumen evenly distributed throughout the ledge (estimated yield, 20 gallons)	81	
Shale, bituminous		10
Shale, brown, slightly carbonaceous	79	
Shale, bituminous		13
Shale, brown, slightly bituminous	4	5
Shale, bituminous		8

Location FF, along Mount Logan trail, sec. 26, T. 7 S., R. 97 W.—Continued.

	Ft.	in.
Shale, brown	2	6
Shale, bituminous		8
Shale, brown, slightly bituminous	12	
Shale, bituminous		7
Shale, brown, slightly bituminous	3	9
Sandstone		3
Shale, brown		4
Sandstone, brown		4
Shale, brown, slightly bituminous		6
Shale, bituminous		5
Shale, brown, slightly bituminous	1	2
Shale, bituminous		8
Shale, brown, fissile		8
Shale, bituminous	1	
Shale, brown, slightly bituminous	3	2
Shale, bituminous (estimated yield, 20 gallons)	1	1
Shale, brown, slightly bituminous	2	10
Sandstone, brown		8
Shale, brown, slightly bituminous	3	4
Shale, bituminous (estimated yield, 30 gallons)		8
Shale, brown, slightly bituminous	3	2
Shale, brown, bituminous	9	8
Shale, brown	2	6
Shale, bituminous (estimated yield, 25 gallons)	2	6
Shale, brown, slightly carbonaceous	1	5
Shale, bituminous (estimated yield, 30 gallons)		9
Shale, brown, slightly bituminous	2	6
Shale, bituminous	1	
Shale, brown, slightly bituminous	5	
Shale, bituminous (estimated yield, 20 gallons)	5	6
Shale, gray, thin bedded	122	
Sandstone, gray	2	
Shale, gray, fine grained, thin, even bedded; this member seems to be uniform throughout	329	
Shale, brown, fissile; weathers in flakes as thin as $\frac{1}{32}$ inch	2	6
Shale, drab, fine grained, fissile	178	
Sandstone, tan		6
Shale, drab, thin bedded; contains thin layers of shaly sandstone	69	
Sandstone, tan		6
Shale, drab, thin bedded	18	
Sandstone, tan, slightly irregular in thickness	1	6
Shale, drab, thin bedded	28	
Sandstone, shaly in lower half	4	
Shale, thin bedded; this member is uniform throughout except that at intervals of 10 to 20 feet there are beds of shaly sandstone as much as 6 inches thick	174	
Sandstone, coarse, oolitic	1	6
Sandstone, fine grained, oolitic	1	6
Shale, drab, fissile	63	
Sandstone, gray	6	
Shale, gray in upper part, brown in lower, fine grained, fissile	147	

Location FF, along Mount Logan trail, sec. 26, T. 7 S., R. 97 W.—Continued.

	Ft.	in.
Shale and sandstone; this member is composed of layers of tan sandy shale and shaly sandstone 6 inches to 2 feet thick	92	
Sandstone, thick bedded, coarse grained	15	
Shale, tan, very sandy, with many layers of shaly sandstone which are as much as 6 inches thick	98	
Sandstone, tan, thick bedded	5	
Shale, tan, sandy; contains layers of shaly sandstone	68	
Shale, red (top of Wasatch formation).		
Total section	1,806	10
Total shale yielding more than 15 gallons to the ton	91	6

Location GG, east side of Mount Callahan, along trail, sec. 15, T. 7 S., R. 96 W.

	Ft.	in.
Shale, hard, black, curly		6
Shale, lean	10	
Shale, hard, black, curly (sample 332; 21 gallons)	1	11
Shale, medium	2	
Shale, hard, black, curly (sample 331; 25 gallons)	2	6
Shale, lean to barren	7	
Shale, hard (estimated yield, 15 gallons)	3	
Shale, lean to barren	17	
Shale, hard (estimated yield, 40 gallons)	1	6
Shale, lean to barren, mostly concealed	154	
Shale, mostly lean; some yielding 15 gallons at top	53	
Shale (estimated yield, 26 gallons)	1	4
Shale, lean	4	6
Shale (estimated yield, 26 gallons)	2	4
Shale, lean	5	
Shale (estimated yield, 26 gallons)	2	
Shale, mostly lean	9	6
Shale, rich at bottom (sample 330; 26 gallons)	2	7
Shale, thin bedded, mostly lean	5	6
Shale, thin bedded, rich		10
Shale, thin bedded, mostly lean	33	
Shale, thin bedded (sample 329; 11 gallons)	3	6
Sandstone, concretionary	2	6
Shale, thin bedded, lean	5	
Shale, hard (estimated yield, 20 gallons)		8
Shale, thin bedded, lean	16	
Shale, hard (estimated yield, 25 gallons)	1	8
Shale, thin bedded, lean	4	8
Shale, thin bedded (estimated yield, 30 gallons)	1	
Shale, lean	3	
Shale, thin bedded (estimated yield, 30 gallons)	1	
Shale, thin bedded, lean	13	
Shale, hard, rich		5
Shale, thin bedded, lean	5	
Shale, thin bedded (sample 328; 24 gallons)	5	10
Shale, thin bedded, lean	5	

Location GG, east side of Mount Callahan, along trail, sec. 15, T. 7 S., R. 96 W.—Continued.

	Ft.	in.
Sandstone		6
Shale, lean	3	
Shale, like sample 327	2	6
Shale, thin bedded / Sandstone (not sampled) / **Shale,** thin bedded (sample 327; 42 gallons)	1	
		1
	9	2
Shale, thin bedded, lean	2	6
Shale, thin bedded, rich	1	8
Shale, lean	3	
Shale, thin bedded, rich / Shale, lean (not sampled) / **Shale,** thin bedded, rich (sample 326; 37 gallons)	3	6
		10
	1	6
Shale, lean	2	8
Shale, hard (estimated yield, 40 gallons)	1	
Shale, mostly lean	3	8
Shale, thin bedded (sample 325; 32 gallons)	7	5
Shale, mostly lean	11	
Sandstone		3
Shale, lean	1	8
Shale (estimated yield, 30 gallons)		7
Shale, thin bedded, lean	2	3
Shale, thin bedded (estimated yield, 30 gallons)	1	1
Shale, mostly lean	4	
Sandstone, irregular		10
Shale, thin bedded (estimated yield, 15 gallons; richest at top)	2	3
Shale, sandy, lean	21	
Sandstone, coarse, irregular	7	
Shale, sandy, lean	8	
Sandstone, fine grained, irregular		6
Shale, mostly lean and covered	17	
Shale, thin bedded, like sample 324	1	3
Shale, thin bedded, lean	2	3
Shale, thin bedded, rich		8
Sandstone (not sampled)		3
Shale, lean (not sampled)	1	9
Sandstone (not sampled)		1
Shale, lean (not sampled)		6
Sandstone (not sampled)		1
Shale, thin bedded, rich (sample 324; 29 gallons)	2	2
Shale, thin bedded, mostly lean	15	
Shale, thin bedded, rich		6
Shale, thin bedded, lean	2	4
Shale, thin bedded	1	8
Shale, lean (not sampled)		7
Shale, thin bedded (sample 323; 25 gallons)	1	7
Shale, white, mostly covered		
Total section	539	4
Total shale yielding more than 15 gallons to the ton	68	4
Total shale yielding more than 30 gallons to the ton	31	3

Location HH, along new Cottonwood Gulch trail, sec. 16, T. 6 S., R. 95 W.

	Ft.	in.
Mostly covered to top	200±	
Shale, black, twisted (sample 350; 28 gallons)	5	
Shale, covered	5	
Shale, black, twisted (samples 349; 21 gallons)	7	

Location HH, along new Cottonwood Gulch trail, sec. 16, T. 6 S., R. 95 W.—Continued.

	Ft.	in.
Covered	10	
Shale, black, twisted (sample 348; 17 gallons)	2	
Mostly covered	150	
Shale, hard, dark (estimated yield, 37 gallons)	1	4
Shale, hard (estimated yield, 16 gallons)	10	4
Shale, hard (sample 347; 16 gallons)	6	1
Shale, hard (estimated yield, 16 gallons)	36	
Shale (estimated yield, 35 gallons)	1	6
Shale, lean	3	6
Shale, thin bedded (sample 346; 12 gallons)	3	4
Shale, lean	8	6
Shale, hard (estimated yield, 37 gallons)	1	6
Shale, thin bedded (estimated yield, 10 to 15 gallons)	8	
Shale, hard (estimated yield, 37 gallons)	1	4
Shale, lean	5	10
Shale (estimated yield, 35 gallons)	2	
Shale, lean	3	6
Shale, hard (sample 345, 37 gallons)	2	8
Shale (estimated yield, 10 gallons)	12	
Shale, hard, dark (sample 344; 31 gallons)	2	7
Shale, hard (estimated yield, 13 gallons)	23	6
Shale, hard (sample 343; 13 gallons)	6	4
Shale, hard (estimated yield, 12 gallons)	7	
Shale, hard (sample 342; 12 gallons)	7	1
Shale, hard (estimated yield, 12 gallons)	12	
Shale, hard (sample 341; 21 gallons)	6	6
Shale, lean	6	
Shale, hard (sample 340; 13 gallons)	3	2
Shale, lean	3	8
Shale, hard (sample 339; 16 gallons)	5	
Shale, lean	2	10
Shale, hard (sample 338; 22 gallons)	6	8
Shale, lean	1	
Shale, hard (sample 337; 27 gallons)	3	
Shale, lean	10	
Shale, hard (sample 336; 28 gallons)	6	8
Shale, hard (sample 335; 26 gallons)	3	7
Sandstone (not sampled)		1
Shale, hard (sample 335; 26 gallons)	5	6
Shale, lean	10±	
Sandstone		8
Shale, hard, medium rich	8	
Shale, hard (sample 334; 40 gallons)	20	2
Shale, lean	1	10
Shale, hard (sample 333; 44 gallons)	5	4
Total section	654	7
Total shale yielding more than 15 gallons to the ton	141	9
Total shale yielding more than 30 gallons to the ton	37	1

Location II, at head of Porcupine Creek, sec. 26, T. 7 S., R. 94 W.

[Beds badly weathered.]

	Ft	in.
Shale, alternating rich and lean layers, mostly thin bedded; exposed, but not examined	200+	
Shale, thin bedded (sample 356; 13 gallons)	8	8
Shale, barren		6
Shale, thin bedded (sample 355; 16 gallons)	4	
Shale, lean	2	2
Shale, thin bedded (sample 354; 15 gallons)	5	
Shale, thin bedded, lean	5	
Shale, thin bedded, rich (sample 353, lower 2 feet, rest not accessible; 30 gallons)	7	8
Shale, thin bedded, mostly lean	75±	
Sandstone, very coarse, cross-bedded	6	
Shale, barren	3	
Sandstone, coarse	1	
Shale, lean	1	
Shale, thin bedded, lean (sample 352; 14 gallons)	2	10
Shale, thin bedded (sample 351; 6 gallons)	2	3
Shale, lean (sample 351; 6 gallons)	1	9
Shale, thin bedded (sample 351; 6 gallons)	1	1
Sandstone, coarse	10	
Shale and sandstone, mostly lean white shale with thin beds of sandstone	200±	
Total section	536±	
Total shale yielding more than 15 gallons to the ton	16	8
Total shale yielding more than 30 gallons to the ton	7	8

Location JJ, east side of Wallace Creek, sec. 10, T. 8 S., R. 95 W.

	Ft.	in.
Covered to top of hill.		
Shale, (sample 361, 27 gallons)	3	4
Shale, lean	6	
Shale, hard, black (sample 360; 37 gallons)	1	4
Shale, (estimated yield, 25 gallons)	2	
Shale, lean	15	
Shale, hard, black (estimated yield, 37 gallons)	1	
Shale, lean	6	
Shale, (sample 359; 24 gallons)	5	5
Shale, covered	10	
Shale, rich (sample 358; 33 gallons)		10
Shale (sample 358; 33 gallons)	1	
Shale, mostly covered, lean	23	
Shale, hard (estimated yield, 30 gallons)	1	8
Shale, burned	24	6
Shale, hard (estimated yield, 25 gallons)	2	6
Shale, medium rich, burned	16	6
Shale, hard (estimated yield, 25 gallons)	2	

Location JJ, east side of Wallace Creek, sec. 10, T. 8 S., R. 95 W.—Continued.

	Ft.	in.
Shale (probable yield, less than 10 gallons)	13	
Shale, hard (estimated yield, 30 gallons)	1	2
Shale; may be burned but probably not very rich when fresh	15	
Shale, hard (estimated yield, 30 gallons)	1	3
Shale, lean	5	
Shale, thin bedded (probable yield, 30 gallons)	1	6
Shale, lean	24	
Shale, thin bedded (estimated yield, 7 gallons)	5	6
Shale, lean	5	
Shale, thin bedded (estimated yield, 10 gallons)	1	
Shale, thin bedded (estimated yield, 5 gallons)	3	
Shale, thin bedded (estimated yield, 10 gallons)		7
Shale, lean	6	3
Shale, thin bedded (sample 357; 7 gallons)	3	1
Shale, massive (estimated yield, 7 gallons)	8	
Shale, thin bedded (estimated yield, 7 gallons)	13	7
Shale, lean	20±	
Total section	249±	
Total shale yielding more than 15 gallons to the ton	38	2
Total shale yielding more than 30 gallons to the ton	9	11

Location KK, east side of Durant Gulch, sec. 5, T. 9 S., R. 95 W.

	Ft.	in.
Covered to top of hill.		
Shale, hard, massive, twisted (sample 366; 27 gallons)	3	
Shale, lean	7	
Shale, hard, massive, twisted (sample 365 A; 33 gallons)	4	8
Shale, lean to medium rich	5	
Shale, massive (sample 365; 36 gallons)	1	10
Shale, massive, lean	8	
Shale, hard, massive (estimated yield, 22 gallons)	1	6
Shale, massive, lean	8	
Shale, hard, massive (sample 364; 22 gallons)	4	8
Covered, mostly lean	35	
Shale, massive, twisted (estimated yield, 30 gallons)	1	6
Covered	30	
Shale, massive (estimated yield, 20 gallons)	2	
Covered	40	
Shale, massive (estimated yield, 20 gallons)	1	
Covered, mostly lean	50	

Location KK, east side of Durant Gulch, sec. 5, T. 9 S., R. 95 W.—Continued.

	Ft.	in.
Shale, mostly lean	25	
Shale, thin bedded (estimated yield, 21 gallons)	12	
Shale, thin bedded (sample 363; 21 gallons)	6	10
Shale, massive, lean	2	2
Shale, thin bedded (estimated yield, 20 gallons)	1	4
Shale, lean	12	
Shale, lean	8	
Shale (estimated yield, 20 gallons)		7
Shale (estimated yield, 30 gallons)		6
Shale, lean	5	
Shale, hard (estimated yield, 25 gallons)	1	6
Shale, lean	5	
Shale, hard (estimated yield, 30 gallons)	1	
Shale, lean	7	
Shale, hard (estimated yield, 35 gallons)		6
Shale, lean	5	
Shale, hard (estimated yield, 35 gallons)		3
Covered and lean shale; some thin, rich	80	
Shale, thin bedded (estimated yield, 25 gallons)	1	
Covered, lean	5	
Shale, thin bedded (estimated yield, 30 gallons)	1	2
Shale, thin bedded, (estimated 20 gallons)	3	
Shale, lean	10	
Shale, hard, rich (sample 362; 47 gallons)		7
Shale, thin bedded, medium rich (sample 362; 47 gallons)		6
Shale (leaf), very rich (sample 362; 47 gallons)	1	
Shale, thin bedded, medium rich (sample 362; 47 gallons)	2	6
Shale, lean	1	10
Shale, thin bedded (estimated yield, 30 gallons)		9
Shale, thin bedded, lean	2	4
Shale, thin bedded (estimated yield, 30 gallons)	2	4
Shale, mostly lean and largely covered.		
Total section	408	10
Total shale yielding more than 15 gallons to the ton	57	6
Total shale yielding more than 30 gallons to the ton	14	5

Location LL, about 1 mile above Park Creek ranger station, on east side of Park Creek, sec. 29, T. 10 S., R. 93 W.

	Ft.	in.
To the top of the hill, fairly well exposed and consisting almost entirely of very lean or barren shale; at least	300	
Shale (sample 370; 14 gallons)	8	3
Shale, lean.		
Sandstone		2
Shale, papery (sample 368; 28 gallons)	1	3
Shale, lean (sample 369; 6 gallons)	2	6
Shale, papery (sample 368; 28 gallons)	1	2

Location LL, about 1 mile above Park Creek ranger station, on east side of Park Creek, sec. 29, T. 10 S., R. 93 W.—Continued.

	Ft.	in.
Sandstone		1
Shale, papery (sample 367; 13 gallons)	4	4
Sandstone, coarse, lenticular.		
Shale, barren.		
Total section	317	9
Total shale yielding more than 15 gallons to the ton	2	5

Location MM, Plateau Shale Co.'s prospect pit on east side of Big Creek, sec. 31, T. 10 S., R. 94 W.

	Ft.	in.
Soil.		
Shale (sample 376; 13 gallons)	2	1
Shale, lean	2	
Shale (sample 375; 13 gallons)	2	
Shale, lean	6	
Shale, (sample 373; 37 gallons)	3	1
Shale (sample 374; 15 gallons)		9
Shale (sample 373, 37 gallons)		9
Shale, lean		4

Location MM, Plateau Shale Co.'s prospect pit on east side of Big Creek, sec. 31, T. 10 S., R. 94 W.—Continued.

	Ft.	in.
Shale (sample 372; 24 gallons).	1	3
Shale, lean (not sampled)		4
Shale		5
Shale, lean	2	10
Sandstone		1
Shale (estimated yield, 24 gallons)		9
Shale lean (estimated yield, 10 gallons)	3	3
Sandstone		7
Shale (estimated yield, 24 gallons)	1	
Shale, lean (estimated yield, 10 gallons)	1	
Shale, barren.		
Total section	23	
Total shale yielding more than 15 gallons to the ton	8	
Total shale yielding more than 30 gallons to the ton	3	10

Location NN, above ranger station on Coon Creek, T. 11 S., R. 96 W.

[Rocks very poorly exposed and no rich oil shale showing.]

Section of part of the middle member of the Green River formation exposed on Parachute Creek in sec. 29, T. 5 S., R. 95 W., Colo.

[By E. G. Woodruff.]

	Ft.	in.
Shale, brown, carbonaceous, thin bedded.		
Shale, brown, bituminous; weathers cavernous (estimated yield, 20 gallons)	31	
Shale, brown, thin bedded, slightly bituminous	5	3
Shale, bituminous	7	3
Shale, fissile; contains some seams of bituminous shale	2	9
Shale, brown		5
Shale, bituminous	1	
Shale, thin bedded, slightly bituminous		9
Shale, bituminous		3
Shale, thin bedded, slightly bituminous		9
Shale, brown, fine grained, bituminous; estimated	10	
Shale, brown, thin bedded	26	6
Shale, brown, bituminous (estimated yield, 20 gallons)	4	10
Shale, brown, thin bedded, fine grained	2	6
Shale, brown, slightly bituminous	5	
Shale, fissile, fine grained, thin bedded	6	6
Shale, bituminous (sample, 20 gallons)	5	10
Shale, brown, thin bedded, slightly carbonaceous, moderately calcareous.		
	110	7

Section of part of the middle member of the Green River formation on north side of Kimball Creek, sec. 5, T. 5 N., R. 100 W., Colo.

[By E. G. Woodruff.]

	Feet.
Soil and rock débris.	
Shale, bituminous (samples testing 31.6 and 26.2 gallons were taken from 6 feet of this bed from 12 to 18 feet below the top; the upper half of the bed is believed to be slightly richer than the lower half)	48
Shale, locally very calcareous	35
Shale, bituminous	3
Shale, brown, carbonaceous.	
	86

A sample was taken from an old prospect entry on Conn Creek, Colo., in sec. 1, T. 7 S., R. 98 W. The prospect was opened on what appears to be a lens of bituminous shale, which measures 16 inches in its thickest part. A field test of this shale gave 61.2 gallons of oil to the ton; by a laboratory test the same shale gave 68 gallons, but it is too thin to be of much commercial value.

RESULTS OF DISTILLATION TESTS.

The following table contains the results of distillation tests of all the samples of oil shale collected by the writer or his assistants in northwestern Colorado during several seasons of field work. Each of the samples included material from every part of the bed which it represents. All samples were taken at the outcrop after chipping away the obviously weathered material, but nowhere was absolutely unweathered shale available for tests. At each locality where samples were taken a geologic section of the beds exposed was measured, and a sample was taken of each bed that appeared to be of value. The completeness of sampling and the range in richness of materials sampled are illustrated by section HH (pp. 67–68). This section represents the beds exposed along a newly cut trail, which provides fairly complete exposure of all except the lower part of the main oil-shale zone. A total thickness of 654 feet 7 inches of beds was examined, and 18 samples were taken of beds ranging in thickness from 2 feet to 20 feet 2 inches. The testing of these samples gave accurate information relative to the oil-yielding capacity and the nitrogen content of an aggregate thickness of 103 feet 8 inches of shale, and because of the apparent similarity of other beds not sampled it gives almost as accurate information regarding a total thickness of 216 feet and 2 inches. The samples tested show an aggregate thickness of 88 feet 9 inches of shale yielding more than 15 gallons to the ton and an aggregate thickness of 31 feet 1 inch of shale yielding 30 gallons or more to the ton.

Many of the samples tested during the field work were selected in order that the field man might be better able to judge the value of the beds rather than because they were supposed to be rich.

Results of distillation of samples of oil shale collected in Colorado.

Sample No.	Location. Sec.	T.	R. W.	Thickness of shale sampled.	Yield of oil per short ton of shale.	Gravity of oil at 60° F. Specific gravity.	Baumé.	Yield of gas per short ton of shale.	Yield of ammonium sulphate per short ton of shale.	Nitrogen in shale.	Theoretical equivalent of nitrogen in ammonium sulphate per ton shale.	Sulphur in shale.
				Ft. in.	*Gallons.*		°	*Cubic feet.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
7	9	1 N.	103	2 ½	12.6 +	0.9235	21.6	.....	.....	.....	.....	.....
8	9	1 N.	103	4 8	4.26	.9371	19.4	.....	.....	.....	.....	.....
9	9	1 N.	103	3 10	11.9	.9010	25.4	2,395	7.1	.....	.....	.....
10	9	1 N.	103	3 10	11.3	.9138	23.2	.....	.....	.....	.....	.....
11	9	1 N.	103	1 11	8.22	.....	.....	.....	.....	.....	.....	.....
a12	9	1 N.	103	2 3	8.64	.9290	20.7	.....	.....	.....	.....	.....
13	26	1 N.	100	5	33.6	.8919	27.0	3,034	9.7	.....	.....	.....
14	15	2 N.	98	5	13.3	.9165	22.7	3,034	12.8	.....	.....	.....
15	15	2 N.	98	1 2	3.0	.....	.....	.....	.....	.....	.....	.....
16	15	2N.	98	1 4	1.9	.....	.....	.....	.....	.....	.....	.....
17	15	2 N.	98	6	21.0	.9059	24.8	3,123	18.2	.....	.....	.....
a18	16	2 N.	98	3 4	22.88	.9290	20.7	.....	.....	.....	.....	.....
19	16	2 N.	98	3 4	6.27	.9327	20.0	.....	.....	.....	.....	.....
20	10	2 N.	98	3	12.6	.9030	25.0	3,512	16.4	.....	.....	.....
21	10	2 N.	98	4 6	26.8	.....	.....	.....	.....	.....	.....	.....
22	15	2 N.	98	3 5¾	15.4	.9310	20.4	3,592	9.0	.....	.....	.....
23	15	2 N.	98	2 2	7.61	.9321	20.2	.....	.....	.....	.....	.....
a24	14	2 N.	98	1 6	6.25+	.9352	19.7	.....	.....	.....	.....	.....
a25	19	2 N.	97	8 1	4.78+	.9109	23.7	.....	.....	.....	.....	.....
26	19	2 N.	97	8 1	3.85	.9050	24.7	.....	.....	.....	.....	.....
27	11	1 N.	97	18 1	8.4	.8946	26.5	1,926	18.3	0.46	43.2	1.08
28	11	1 N.	97	4	14.0	.9090	24.0	2,075	1.0	.....	.....	.....
29	11	1 N.	97	4	12.5	.9082	24.1	.....	8.5	.....	.....	.....
30	11	1 N.	97	4	9.1	.....	.....	.....	10.5	.....	.....	.....
31	11	1 N.	97	17	15.5	.8880	27.6	.....	.....	.....	.....	.....
32	11	1 N.	97	3	40.6	.8838	28.4	3,832	8.5	.54	50.8	.55
33	11	1 N.	97	3	25.5	.8920	26.9	.....	.....	.....	.....	.....
34	11	1 N.	97	5 6½	23.0	.8884	27.6	.....	.....	.....	.....	.....
35	11	1 N.	97	4 2	14.7	.8864	27.9	.....	.....	.....	.....	.....
36	11	1 N.	97	3 3¾	31.0	.8831	28.5	.....	15.8	.....	.....	.....
37	11	1 N.	97	5 8½	23.25	.8877	27.7	.....	.....	.....	.....	.....
38	14	1 S.	97	5 11	25.2	.8955	26.4	4,294	6.3	.....	.....	.....
39	36	1 N.	96	3	13.7	.8986	25.8	.....	8.2	.....	.....	.....
40	36	1 N.	96	3 8	12.5	.8959	26.3	.....	4.48	.....	.....	.....
41	36	1 N.	96	1 4	13.7	.8603	32.7	.....	4.91	.....	.....	.....
42	29	1 N.	97	.31	.....	.....	.....	.....	.....	.....	.....	.....
43	2	3 S.	95	4 9	9.4	.8897	27.4	.....	5.72	.....	.....	.....
44	2	3 S.	95	13 6	6.2	.9025	25.1	.....	3.25	.....	.....	.....
45	32	4 S.	94	9 1	6.1	.9205	22.1	639	2.8	.....	.....	.....
46	16	4 S.	94	5 2	12.5	.9037	23.2	.....	.....	.....	.....	.....
47	27	4 S.	94	2	7.0	.9030	25.4	479	1.7	.....	.....	.....
48	27	4 S.	94	4	15.5	.9331	20.0	.....	.4	.....	.....	.....
49	27	4 S.	94	3	10.5 ½	.8955	26.4	4,071	7.4	.....	.....	.....
50	6	6 S.	94	10	40.6	.8790	29.2	1,916	4.3	.....	.....	.....
51	6	6 S.	94	4 3	28.0	.9126	23.4	4,294	7.3	.46	43.2	.30
52	22	6 S.	95	8	24.5	.8636	32.1	1,198	4.4	.....	.....	.....
53	22	6 S.	95	8	35.0	.8802	29.0	3,500	8.7	.....	.....	.....
54	22	6 S.	95	8	20.7	.8585	33.1	.....	.....	.....	.....	.....
55	22	6 S.	95	13	15.4	.9070	24.3	1,443	3.2	.....	.....	.....
56	22	6 S.	95	15	11.2	.9265	21.1	1,198	4.0	.....	.....	.....
57	1	7 S.	98		63.3	.9115	23.6	4,549	7.0	1.22	115.0	.95
187	27	7 S.	100	3 8	21	.898	25.8	.....	3.92	.....	.....	.....
188	27	7 S.	100	5	38	.891	27.1	.....	7.38	.....	.....	.....
189	27	7 S.	100	3 6	22	.899	25.6	.....	4.54	.....	.....	.....
190	36	5 S.	96	6 4	18	.892	26.9	.....	8.70	.....	.....	.....
191	36	5 S.	96	5 4	19	.901	25.4	.....	5.23	.....	.....	.....
192	36	5 S.	96	2 6	36	.890	27.3	.....	5.71	.....	.....	.....
193	36	5 S.	96	5	42	.892	26.9	.....	6.20	.....	.....	.....
221	16	1 S.	100	12 9	13	.....	.....	.....	.....	.28	26.4	.....
222	16	1 S.	100	6	9	.....	.....	.....	.....	.20	18.8	.....
223	16	1 S.	100	7 2	21	.....	.....	.....	.....	.33	31.1	.57
224	16	1 S.	100	15 6	18	.....	.....	.....	.....	.32	30.1	.....
225	16	1 S.	100	8 10	25	.....	.....	.....	.....	.48	45.2	.....
226	16	1 S.	100	5 9	30	.....	.....	.....	.....	.52	49.0	.....
227	16	1 S.	100	7 2	21	.....	.....	.....	.....	.33	31.1	.27
228	16	1 S.	100	5 2	17	.....	.....	.....	.....	.26	24.5	.....
229	16	1 S.	99	9 4	25	.....	.....	.....	.....	.....	.....	.....
230	21	2 S.	100	5 3	22	.....	.....	.....	.....	.25	23.6	.....
231	21	2 S.	100	4	12	.....	.....	.....	.....	.36	34.9	.....
232	21	2 S.	100	3 1	20	.....	.....	.....	.....	.41	38.6	.30
233	21	2 S.	100	6 7	20	.....	.....	.....	.....	.51	48.0	.44
234	21	2 S.	100	6 10	23	.....	.....	.....	.....	.52	49.0	.54

a Distilled with steam.

Results of distillation of samples of oil shale collected in Colorado—Continued.

Sample No.	Location.			Thickness of shale sampled.	Yield of oil per short ton of shale.	Nitrogen in shale.	Theoretical equivalent of nitrogen in ammonium sulphate per ton shale.	Sulphur in shale.
	Sec.	T.	R. W.					
				Ft. in.	*Gallons.*	*Per cent.*	*Pounds.*	*Per cent.*
235	21	2 S.	100	2 4	34	0.57	53.7	.....
236	21	2 S.	100	7 9	18	.37	34.8	.....
237	21	2 S.	100	6 10	11	.27	25.4	.....
238	21	2 S.	100	4 6	31	.59	55.6	.....
239	21	2 S.	100	7	21	.32	30.1	0.48
240	21	2 S.	100	5 6	22	.34	31.8	.55
241	21	2 S.	100	3 7	30	.44	41.4	.55
242	21	2 S.	100	1 11	28	.35	32.8	.63
243	21	2 S.	100	4 10	26	.45	42.4	.55
244	21	2 S.	100	8 7	25	.41	38.6	.56
245	14	3 S.	100	3	7	.17	16.0	.63
246	14	3 S.	100	5	10	.27	25.4	.....
246A	14	3 S.	100	5 2	24	.44	41.4	.58
247	14	3 S.	100	8 9	22	.46	43.5	.70
248	14	2 S.	100	5 7	33	.41	38.6	.....
249	14	3 S.	100	7	22	.56	52.8	1.41
250	14	3 S.	100	7 2	27	.44	41.4	.67
251	14	3 S.	100	7 11	26	.45	42.4	.81
252	14	3 S.	100	8 6	22	.49	46.1	.60
253	14	3 S.	100	4 3	22	.46	43.5	.32
254	4	4 S.	99	6 2	31	.51	48.0	.62
255	4	4 S.	99	7 5	26	.42	39.6	.67
256	4	4 S.	99	12 5	27	.43	40.5	.86
257	4	4 S.	99	10 9	34	.72	67.8	.....
258	4	4 S.	99	3 4	18	.27	25.4	.....
259	4	4 S.	99	7 11	24	.38	35.9	.42
260	15	4 S.	100	18	24	.47	44.3	.30
261	15	4 S.	100	3	22	.42	39.6	.33
262	15	4 S.	100	3 2	25	.47	44.3	.34
263	15	4 S.	100	4 10	29	.50	47.1	.94
264	15	4 S.	100	3 4	23	.32	30.1	.61
265	15	4 S.	100	3 9	30	0.53	49.9	0.75
266	15	4 S.	100	3 2	34	.55	51.8	.....
267	15	4 S.	100	4 4	25	.42	39.6	.38
268	15	4 S.	100	4 3	22	.50	47.1	.49
269	15	4 S.	100	8 8	23	.47	44.3	.25
270	15	4 S.	100	4 2	16	.35	32.8	.....
271	31	4 S.	99	3 6	24	.46	43.5	.40
272	31	4 S.	99	5 6	20	.41	38.6	.34
273	31	4 S.	99	5 4	23	.38	35.9	.52
274	31	4 S.	99	9 9	6	.21	19.8	.....
275	31	4 S.	99	6 6	22	.41	38.6	.21
276	31	4 S.	99	5 9	20	.46	43.5	.35
277	31	4 S.	99	5 8	23	.44	41.4	.36
278	31	4 S.	99	8 6	30	.49	46.1	.....
279	31	4 S.	99	6	13	.27	25.4	.....
280	31	4 S.	99	7 6	12	.37	34.8	.....
281	31	4 S.	99	4 10	9	.29	27.3	.....
282	9	5 S.	100	5 8	26	.43	40.5	.51
283	9	5 S.	100	5 3	27	.54	50.8	.50
284	9	5 S.	100	6 2	44	.58	54.6	.....
285	9	5 S.	100	10	22	.30	28.3	.17
286	9	5 S.	100	6 8	9	.44	41.4	.....
287	9	5 S.	100	8 4	12	.21	19.8	.....
288	21	6 S.	100	5	18	.30	28.3	.....
289	21	6 S.	100	5	32	.60	56.5	.....
290	21	6 S.	100	4	13	.30	28.3	.....
291	21	6 S.	100	4 11	17	.45	42.4	.....
292	31	6 S.	100	4 4	70	.85	80.1	.....
293	6	7 S.	100	9 10	43	.76	71.8	1.05
294	16	6 S.	99	4 5	21	.34	31.9	.32
295	16	6 S.	99	6	24	.43	40.5	.45
296	16	6 S.	99	4 7	34	.73	68.7	.....
297	16	6 S.	99	7 4	17	.33	31.1	.29
298	16	6 S.	99	8 1	21	.36	34.9	.20
299	16	6 S.	99	3 8	11	.....	.....	.....
300	16	6 S.	99	5 3	17	.37	34.8	.....

Results of distillation of samples of oil shale collected in Colorado—Continued.

Sample No.	Location.			Thickness of shale sampled.	Yield of oil per short ton of shale.	Nitrogen in shale.	Theoretical equivalent of nitrogen in ammonium sulphate per ton shale.	Sulphur in shale.
	Sec.	T.	R. W.					
				Ft. in.	*Gallons.*	*Per cent.*	*Pounds.*	*Per cent.*
301	16	6 S.	99	6 6	13	0.24	22.6	0.26
302	3	6 S.	98	5 2	23	.51	48.0	1.03
303	3	6 S.	98	4 2	25	.....	.....	.86
304	3	6 S.	98	2 8	38	.63	59.3	1.07
305	3	6 S.	98	8 11	45	.80	75.3	.....
306	3	6 S.	98	5 3	21	.36	34.9	.33
307	3	6 S.	98	2 10	18	.30	28.3	.....
308	3	6 S.	98	2 9	37	.72	67.8	.72
309	3	6 S.	98	8 11	18	.76	71.8	.48
310	.....	7 S.	100	1 5	14	.19	17.9	.18
311	.....	7 S.	100	2 6	22	.35	32.8	.33
312	.....	7 S.	100	5 10	15	.23	21.7	.....
313	.....	7 S.	100	15	23	.47	44.3	.34
314	.....	7 S.	100	5	32	.49	46.1	.31
315	.....	7 S.	100	8	25	.44	41.4	.33
316	27	7 S.	100	4 8	44	.68	63.8	.....
317	.....	8 S.	99	5 10	38	.62	58.4	.38
318	.....	8 S.	99	2	12	.....	.....	.....
319	.....	8 S.	99	3 7	15	.31	29.2	.....
320	.....	8 S.	99	2 4	18	.....	.....	.....
321	16	7 S.	97	7 2	50	.69	65.0	.....
322	22	5 S.	94	6	52	.91	85.7	.....
323	15	7 S.	96	3 3	25	.42	39.6	.36
324	15	7 S.	96	2 10	29	.36	34.9	.....
325	15	7 S.	96	7 5	32	.41	38.6	.26
326	15	7 S.	96	5	37	.45	42.4	.....
327	15	7 S.	96		42	.68	63.8	.77
328	15	7 S.	96	5 10	24	.44	41.4	.37
329	15	7 S.	96	3 6	11	.14	13.2	.....
330	15	7 S.	96	2 7	26	.30	28.3	.16
331	15	7 S.	96	2 6	25	.63	59.3	.81
332	15	7 S.	96	1 11	21	.52	49.0	.60
333	15	6 S.	95	5 4	44	.64	60.2	.82
334	16	6 S.	95	20 2	40	.74	69.6	1.05
335	16	6 S.	95	9 1	26	.52	49.0	.39
336	16	6 S.	95	6 8	28	.36	34.9	.38
337	16	6 S.	95	3	27	.43	40.5	.43
338	16	6 S.	95	6 8	22	.34	31.9	.45
339	16	6 S.	95	5	16	.....	.....	.....
340	16	6 S.	95	3 2	13	.23	21.6	.....
341	16	6 S.	95	6 6	21	.29	27.3	.41
342	16	6 S.	95	7 1	12	.....	.....	.....
343	16	6 S.	95	6 4	13	.18	16.9	.44
344	16	6 S.	95	2 7	31	.46	43.5	.68
345	16	6 S.	95	2 8	37	.26	24.5	.68
346	16	6 S.	95	3 4	12	.20	18.8	.....
347	16	6 S.	95	6 1	16	.....	.....	.....
348	16	6 S.	95	2	17	.45	42.4	.....
349	16	6 S.	95	7	21	.58	54.6	.43
350	16	6 S.	95	5	28	.43	40.5	.44
351	26	7 S.	94	5 1	6	.22	20.6	.25
352	26	7 S.	94	2 10	14	.13	12.2	.13
353	26	7 S.	94	7 8	30	.47	44.3	.27
354	26	7 S.	94	5	15	.32	30.1	.26
355	26	7 S.	94	4	16	.25	23.6	.16
356	26	7 S.	94	8 8	13	.....	.....	.....
357	10	8 S.	95	3 1	7	.20	18.8	.44
358	10	8 S.	95	1 10	33	.52	49.0	.39
359	10	8 S.	95	5 5	24	.43	40.5	.....
360	10	8 S.	95	1 4	37	.62	58.4	.78
361	10	8 S.	95	3 4	27	.47	44.3	.66
362	5	9 S.	95	4 6	47	.75	70.6	.27
363	5	9 S.	95	6 10	21	.39	36.7	.....
364	5	9 S.	95	4 8	22	.42	39.6	.82
365	5	9 S.	95	1 10	36	.61	57.4	.51
365A	5	9 S.	95	4 8	33	.33	.....	.53

Results of distillation of samples of oil shale collected in Colorado—Continued.

Sample No.	Location.			Thickness of shale sampled.	Yield of oil per short ton of shale.	Nitrogen in shale.	Theoretical equivalent of nitrogen in ammonium sulphate per ton shale.	Sulphur in shale.
	Sec.	T.	R. W.					
				Ft. in.	*Gallons.*	*Per cent.*	*Pounds.*	*Per cent.*
366	5	9 S.	95	3	27	0.52	49.0	0.53
367	29	10 S.	93	4 4	13	.10	9.4	.....
368	29	10 S.	93	1 2	28	.23	21.7	.18
369	29	10 S.	93	2 6	6	.13	12.2	.....
370	29	10 S.	93	8 3	14	.14	13.2	.....
371	31	10 S.	94	3 2	36	.38	35.9	.27
372	31	10 S.	94	1 8	24	.25	23.6	.18
373	31	10 S.	94	9	15	.19	17.9	.....
374	31	10 S.	94	3 10	37	.49	46.1	.39
375	31	10 S.	94	2	13	.....	.....	.....
376	31	10 S.	94	2 1	13	.21	19.8	.....

DEVELOPMENTS.

One of the first attempts to make use of oil shale was prompted by the idea that certain black shale occurring above the cliffs in sec. 1, T. 7 S., R. 97 W., was lignite. A tunnel 30 or 40 feet long was driven on the bed, which is only 16 inches thick, but was finally abandoned. Later other persons continued the prospecting, thinking the material was a natural asphalt. Still more recently the property has been taken up as oil-shale land.

After the work of Woodruff and Day in 1913 considerable prospecting was carried on, and early in 1917 the Oil Shale Mining Co. installed near the head of Dry Fork, 22 miles west of De Beque, Colo., a small retort patterned in general after the Henderson retort used in Scotland. So far as known to the writer this was the first large retort erected in the field to distill oil from the western shale.

The possibilities of producing oil from oil shale at a profit have within the last few years attracted the attention of many persons, and rapid strides have already been taken toward this end, but because of the newness of the undertaking and the many attendant difficulties the results are rather slow in appearing.

At the time of the writer's last visit, in October, 1918, evidences of oil-shale activities were apparent everywhere. The steep slopes of many of the cliffs leading to the outcrops of the oil-shale beds are scored with trails and newly built roads, which will make it possible to reach the outcrops without the use of an airplane. So-called "assessment pits," many of which in reality are nothing more or less than small excavations dug at random on the hillside and are neither essential or even of assistance in the ultimate development of the shale, have been dug on most of the claims, in order to comply

with the law which required that $100 be spent on each claim each year. A large part of the land underlain by valuable beds of oil shale and within the reach of the railroad has now been filed upon as mineral land and is therefore covered by the preferential rights recognized by the leasing law recently enacted.[11] Many applications for patent to oil-shale land have been filed with the General Land Office, and by July 1, 1922, the Government had issued final patent to about 29,000 acres of oil-shale land, most of it near Grand Valley. Several small shale camps, including one or more cabins, shops, etc., have been constructed in the valleys adjacent to the outcrops of the oil-shale beds, and in a few places the operations include retorts, tramways, and other paraphernalia to be used in the production of shale oil.

The American Shale Refining Co., with properties on Conn Creek, in 1918 installed a 3,000-foot aerial tramway to bring the shale from its outcrop down to the distilling plant to be built just above the mouth of Baker Gulch, on the east side of Conn Creek about 12 miles north of De Beque. Practically all the material necessary for the installation of a 150-ton retort of the Wingett pattern was assembled on the property, but its erection has been postponed. The company's equipment also includes several comfortable cabins.

The Colorado Carbon Co., whose properties lie at the head of Kimball Creek, 25 miles northwest of De Beque, has a neat little camp including three or four log cabins and in October, 1918, had an aerial tramway nearly installed. Most of the research work of this company has been done at laboratories in St. Louis.

The Continental Oil Shale Mining & Refining Co. during 1920 erected and began the operation of a retorting plant on its property on Piceance Creek west of Rio Blanco post office. The retort (known as the Colorado Continuous retort) consists of a vertical cast-iron chamber 2 feet in diameter and 22 feet high set in a brick furnace. The shale, crushed to one-half inch size, is fed from a hopper into the retort at the top and lowered by a helical conveyor that regulates the speed at which it passes through the heated zone. Oil and permanent gases produced in the distillation are used in the furnace, to supply the heat for distillation. Vapors are withdrawn from the retort through a number of pipes at different elevations and carried through air and water cooled condensers, where the oil is condensed. Spent shale is removed by a mechanical device through a water seal at the bottom of the retort. The plant has a rated capacity of 50 tons of shale a day.

The Grandvalley Oil & Shale Co. during 1920 constructed an automobile road from Parachute Creek up Starkey Gulch to its

[11] U. S. General Land Office Circ. 671, 1920.

plant site, 6 miles northwest of Grand Valley, and was laying foundations for the installation of a Stalmann retorting plant.

The Index Shale Oil Co. in 1921 completed the installation of a Brown rotary retorting plant at the foot of Mount Blaine, about 16 miles northwest of De Beque. The retort consists of a huge cylinder 72 feet long by 3 feet in diameter set horizontally inside of a brick fireplace. The cylinder is made in three sections, each of which is revolved independently of the other two. Raw shale is to be fed into one end, and the spent shale discharged from the other. The equipment is set up in a most businesslike manner, and accessories consist of steam boilers, crushers, condensers, etc.

The March Oil Shale Co., whose property is in Wheeler Gulch 5 miles north of Grand Valley, by May 1, 1921, had completed the installation of a 4,000-foot surface tramway connecting its mine site on the cliffs above with the plant site 1,700 feet below. Grading and other preparations had been made for the installation of a Taff retort, machinery for which was being assembled on the ground.

The Monarch Oil Shale Co. during the winter of 1920–21 installed a 50-ton Ginet retort on the west side of Conn Creek about 13 miles north of De Beque. The plant includes also condensers, crushers, bunk house, tanks, etc. The retort consists of a large cylinder set horizontally in a brick furnace. Crushed shale is fed into one end and carried through the retort by a series of buckets or scrapers arranged about a revolving central shaft. The vapors are conveyed to air-cooled condensers, and the uncondensed gas is used as fuel. The apparatus is equipped with burners which utilize either gas or crude oil. The shale is crushed at the mine mouth, high on the cliff above the retort, and conveyed thence by gravity through a 4-inch pipe to the storage bin, immediately above the retort. The plant was put into operation in April, 1921, and has been operated intermittently.

The Mount Logan Oil Shale Mining & Refining Co. has installed an aerial tramway more than a mile long connecting its mine, near the top of Mount Logan, and its retorting plant, near the base of the mountain, about 4 miles northeast of De Beque. The single-unit Simplex retort completed early in 1920 consists of an inclined cast-iron hearth about 30 feet long and 3 feet wide. The retort chamber above the hearth is about 3 inches deep, and its top is penetrated by five large take-off pipes for the removal of vapors. Finely crushed shale is fed into the upper end of the retort by a screw conveyor and carried down across the hearth by the assistance of 15 geared agitators, each of which scrapes the bottom of the retort, moving in a circular direction. Spent shale is removed at the lower

end of the retort through a shale seal. Crude oil is used in two burners located under the upper end of the hearth. The mine, near the top of Mount Logan, consists of several entries and rooms laid out after the plan of coal-mining operations, and several hundred tons of shale has been mined and taken down to the plant site below. A power-driven auger drill is used in drilling holes for blasting out the shale.

The Oil Shale Mining Co., whose properties are near the head of Dry Fork, about 20 miles west of De Beque, was the first to install a working retort. (See Pl. XIII, *B*.) This retort was later dismantled and moved to a more favorable location near by. Material for a total of six Henderson retorts is on the ground, and the new mill site is connected with the shale quarry by a 1,000-foot aerial tramway.

The Pure Oil Co. during 1921 put down a diamond-drill test hole to a depth of 825 feet near the east end of Battlement Mesa and made complete chemical examination of the entire 3½-inch core that was thus obtained, as well as of numerous surface samples of the oil shale of the district. Distillation tests together with fairly complete chemical analyses of the raw shale, the spent shale, and the gases evolved were made under the supervision of Paul S. Nice in a specially equipped laboratory at Glenwood Springs. The work included the chemical examination of about 1,500 samples of oil shale.

The Union Oil Co. of California by July 1, 1922, had made patent application for practically all of its 17,000 acres of oil-shale placer claims near the forks of Parachute Creek, north of Grand Valley. The company has acquired a considerable area of ranch land adjacent to its oil-shale property, to be used as camp, reduction, and waste-dump sites in connection with the development of the oil shale. It also owns 200 acres near Grand Valley which is to be used for reduction and refinery operations. The company's research work during 1921 included the careful mapping of the oil-shale outcrops on the property, the careful and complete sectioning and sampling of the Green River formation (2,300 feet thick), the making of about 6,000 laboratory tests on 900 samples of oil shale, and the shipment of several large samples of the shale to the company's laboratories in California, where the shale is being used in extensive research operations. The company's field camp, about 12 miles north of Grand Valley, includes three well-constructed buildings, one of which is used as a field laboratory.

In Denver experiments are being carried on by a number of persons looking toward the perfection of processes for the distillation of oil shale, and several small plants have been set up to test their efficiency.

At the University of Colorado at Boulder experimental and research work has been carried on by R. D. George, State geologist, chemists of the United States Bureau of Mines, and others interested in the oil shale.

At Golden considerable valuable research work has been carried on by the Colorado School of Mines.

IDAHO.

GENERAL CONDITIONS.

From the Idaho-Montana State line southeastward for a distance of 75 miles there are no outcrops of the Phosphoria formation, which at many places in the Rocky Mountain region contains black bituminous shale. The rocks reappear in the Teton and Big Hole mountains along and near the Idaho-Wyoming State line and thence southward are to be seen in most of the mountains all the way to Ogden, Utah. They crop out along the Salt River Range in Wyoming and also encircle the Uinta Mountains of northeastern Utah. Throughout the region brown or black shale is associated with the phosphate rock in beds whose thickness ranges from 50 to more than 200 feet. Wherever these black shales crop out they were prospected by the early settlers for coal. More recently new openings have been made at a few points for the mining of phosphate rock. Unweathered samples of the shales were obtained in the mines and prospects at numerous places that can be regarded as representative of the area. The negative results from the distillation of the samples collected from these areas therefore prove that, however rich in hydrocarbons it may once have been, the black shale of the Phosphoria formation in southeastern Idaho and adjacent parts of Wyoming and Utah is not now to be regarded as oil shale, there being but few samples that yield as much as 1 gallon of oil to the ton.

In all the above-mentioned mountain ranges the Phosphoria formation probably includes beds of phosphate rock that is sufficiently low in iron and alumina to meet commercial requirements.

SECTIONS AND TESTS.

Detailed measurements of the Phosphoria beds show considerable variations from place to place. The following section published in a report by Richards and Mansfield[12] illustrates well the general character of the formation as exposed in Georgetown Canyon, Idaho. Although carbonaceous shales make up a large part of the section at this point, no samples on distillation yielded more than a trace of oil.

[12] Richards, R. W., and Mansfield, G. R., Preliminary report on a portion of the Idaho phosphate reserve: U. S. Geol. Survey Bull. 470, pp. 387-388, 1911.

Section of Phosphoria formation in Georgetown Canyon, Idaho.

Field No. of specimen.		P_2O_5.	Equivalent to $Ca_3(PO_4)_2$.	Thickness.
		Per cent.	*Per cent.*	*Ft. in.*
144-A	Shale, calcareous, or muddy limestone, brown, weathering into irregular chip fragments; effervesces vigorously	3.5	7.7	25 6
144-B	Phosphate rock, oolitic, weathering brown or gray; effervesces slightly; lower 1½ inches somewhat cherty	35.8	78.4	6
144-C	Shale, hard, brown, calcareous at the top; effervesces vigorously	Trace.		1
144-D	Phosphate rock, coarsely oolitic, gray; effervesces vigorously	37.6	82.3	2 11
144-E	Shale, brownish, earthy, containing 6 inches of phosphate; effervesces considerably	10.0	21.9	1
144-F	Phosphate rock, including *Ft. in.* (*a*) Phosphate rock, oolitic, hard, gray, calcareous 7 (*b*) Phosphate rock, gray, oolitic 6 (*c*) Shale, phosphatic, light brown 4 (Sample shows considerable effervescence.)	21.9	48.0	1 5
144-G	Phosphate rock, including (*a*) Phosphate rock, coarsely oolitic, gray, brittle 1 2 (*b*) Phosphate rock, finely oolitic, brownish gray 4 (*c*) Phosphate rock, coarsely oolitic, dark gray 2 (*d*) Phosphate rock, finely oolitic, brownish gray 4 (*e*) Phosphate rock, coarsely oolitic, gray 7 (*f*) Phosphate rock, finely oolitic, thin bedded 3 (*g*) Phosphate rock, coarsely oolitic, gray 1 4 (Sample effervesces slightly.)	33.3	72.9	4 2
144-H	Phosphate rock, including (*a*) Phosphate rock, medium to finely oolitic, brownish gray 7 (*b*) Shale, phosphatic, brownish, somewhat oolitic 10 (*c*) Phosphate rock, coarsely oolitic 2 (*d*) Phosphate rock, shaly, brown 3	29.3	64.1	1 10
144-I	Phosphate rock, including (*a*) Phosphate rock, coarsely oolitic, brownish-black streaks 1 1 (*b*) Phosphate rock, shale, brown, thin bedded 5 (*c*) Phosphate rock, coarsely oolitic, crumbly 4 (*d*) Phosphate rock, medium to coarsely oolitic 3 (Sample effervesces considerably.)	34.7	76.0	4 10
144-K	Shale, brownish to black, earthy composition, thin bedded, with a few limestone lenses; effervesces slightly	24.2	53.0	8 9
	Limestone, dark, compact, fetid			1 9
144-L	Shale, brownish to black, earthy; effervesces slightly	11.7	25.6	12
144-M	Shale, including (*a*) Shale, brownish black, earthy 7 (*b*) Concealed, not included in sample (probably same as *a* and *c*) 4 7 (*c*) Shale, brownish black, earthy 5 5	15.1	33.1	17
144-N	Shale, black, earthy; effervesces slightly	19.9	43.6	12
144-O	1. Shale, brownish black, earthy 4 2. Limestone, single stratum (not sampled) 2 3. Shale, brownish black, earthy 4 4. Limestone, single stratum (not sampled) 2	21.2	46.4	12
144-P	Shale, black and dark brown, calcareous, earthy; effervesces considerably	25.8	56.5	6
144-Q	Shale, black and dark brown, calcareous earthy; effervesces considerably	24.6	53.9	12
144-R	Limestone, shaly, brownish gray; effervesces vigorously	17.8	39.0	4 10
	Limestone, single stratum			11
	Limestone ("cap lime"), fine, dark gray, fossiliferous			2 3
144-S	Phosphate rock, main bed prospected, coarse to medium, oolitic, gray; contains two or three minor streaks of shaly material; effervesces slightly	36.8	80.6	6 4
144-T	Shale, brown, earthy; effervesces slightly	3.7	8.1	9
	Limestone, massive, underlying the phosphatic series. Thickness not determined.			
				139 9

Samples of shales and other carbonaceous materials were also collected and tested from localities described below:

Samples **426-429**. Black shale, limestone, and phosphate, all greatly sheared, Palisade Creek, T. 2 N., R. 45 E., Idaho. Thickness apparently more than 100 feet; samples represent lithologic variations. Result of distillation: Oil, 3 gallons to the ton; nitrogen, 0.70, 0.76, 0.85, 0.41 per cent, equal to 65.8, 71.7, 80.1, 38.6 pounds of ammonium sulphate to the ton.

Sample **432.** Black shales of Phosphoria formation over phosphate bed, Georgetown Canyon, Idaho; sec. 25, T. 10 S., R. 44 E. Material selected after visiting several prospect tunnels and trenches. Result of distillation: Oil, trace.

Samples **433–441.** Phosphatic black shales of Phosphoria formation about 40 feet thick, associated with phosphate bed in Waterloo mine, near Montpelier, Idaho; sec. 6, T. 13 S., R. 45 E. Result of distillation: Trace of oil in only one sample; others barren.

Samples **442–447.** Phosphatic black shales of Phosphoria formation about 18 feet thick, associated with phosphate beds at Paris mine of Western Phosphate Co., near Paris, Idaho; sec. 8, T. 14 S., R. 43 E. Result of distillation: No oil.

Samples **448–449.** Bloomington Canyon, Idaho; NW. ¼ sec. 21, T. 14 S., R. 43 E. Black phosphatic shales of Phosphoria formation. Thickness of beds sampled 75 feet. Result of distillation: Trace of oil in four samples.

Sample **462.** Taken in Boise opening of "Boise" coal bed at north edge of sec. 36, T. 5 N., R. 43 E., Idaho, by Frank Reeves. Sample represents coal bed 3 feet 5 inches thick. Cretaceous age. Results of test: Oil, 38 gallons to the ton; nitrogen, 0.77 per cent, equal to 72.4 pounds of ammonium sulphate to the ton.

Sample **463.** Black shale from bank of Bear River about 4 miles south of Soda Springs, Idaho, in sec. 29, T. 9 S., R. 42 E. Bed over 4 feet thick; lies nearly flat and extends under basalt flow. Quaternary age (?). Results of test: Oil, 20 gallons to the ton; nitrogen, 0.93 per cent, equal to 87.7 pounds of ammonium sulphate to the ton.

MONTANA.

GENERAL CONDITIONS.

Montana's oil shale has attracted the attention of geologists and the public largely through the attempts to produce oil from the shale near Dillon, in the southwestern part of the State. The shales that are particularly interesting because of their possible value as sources of oil belong to two different formations, the Phosphoria, of Permian age, and the Tertiary beds, of possible Oligocene age. The black shales of the Phosphoria formation are associated with rocks that contain phosphate, and it is possible that the value of the beds for oil, nitrogen, and phosphate combined may make it feasible to develop them commercially, but from tests so far made it appears that the separate values are too low to warrant the utilization of these shales, at least for a long time to come.

Samples of dark shale have been collected by geologists of the United States Geological Survey from formations other than the two mentioned, but tests have shown the shale to be of scientific interest only.

WEST-CENTRAL MONTANA.

GENERAL GEOLOGY.

The beds sampled for oil shale in west-central Montana lie in the Threeforks and Quadrant formations, whose positions and general character are shown in the following generalized geologic section, representative of the area between Whitehall and Logan:

Generalized section in west-central Montana.

	Feet.
Phosphoria formation (Permian):	
Chert and quartzite	0–50
Shale, sandy, with thin phosphate beds (position of oil-shale beds of Dillon field)	0–25
Quadrant formation (Pennsylvanian and late Mississippian):	
Sandstone, quartzitic	300
Impure limestone, shaly sandstone, and more or less black shale. Contains oil shale in western part of Meagher County.	0–60
Sandstone, impure limestone, and sandy shale, generally of brick-red color	75±
Madison limestone (Mississippian):	
Thick massive layers in upper part and thin platy layers toward bottom	1,000
Threeforks formation (Devonian):	
Shale, black	0–3
Sandstone	20–30
Shale, black to dark gray	5–15
Shale, sandy, greenish, interbedded with sandstone and fossiliferous limestone	30±
Limestone, gray	75±

Northward from Lombard, on Missouri River, the Phosphoria formation disappears and the underlying Quadrant formation thins, owing to an unconformity. On the North Fork of Musselshell River, in the Little Belt Mountains, the overlying Ellis formation, of Jurassic age, rests upon limestones of the lower part of the Quadrant, the thick quartzitic sandstone member constituting the upper half of the Quadrant formation being absent. The shales in the lower portion are persistently carbonaceous, but most samples yielded on distillation no more than a trace of oil. The principal exception is in the western part of Meagher County, where the beds locally yield as much as 30 gallons of oil to the ton. This oil-shale facies of the Quadrant formation is not persistent, being most conspicuous in the vicinity of Adell, Meagher County, and disappearing toward the south. Bituminous shales are present in the Little Belt Mountains, the Bridger Range, and farther south, but no samples yielded on distillation more than a trace of oil.

The black shales of the Threeforks formation were sampled in the Bridger Range and at a number of points to the west, near the head of Missouri River. None of the samples yielded more than a few gallons of oil to the ton.

QUADRANT FORMATION.

The richest samples of oil shale from the Quadrant formation came from Meagher County, Mont., about 9 miles south of Adell post office, where shales identified by G. H. Girty on paleontologic evidence as Quadrant were sampled in several prospects by E. T. Hancock in 1917.

Here and at various points as far east as the Bridger Range the black shales have been prospected for coal, and some of the pits dug years ago are still open for sampling. The Quadrant shales were investigated and sampled at several other localities, but the amount of oil obtained on distillation of the samples was insignificant. Descriptions of localities of the Quadrant shale visited are given below.

Samples **377–382.** About 9 miles south of Adell post office, Meagher County, Mont.; investigated by E. T. Hancock. Samples 377, 378, and 379 came from a landslide exposure at the head of Freeman Creek, on the F. C. Campbell ranch, near the line between secs. 28 and 33, T. 14 N., R. 2 E.

Sample **377** came from a thin bed near the base of the exposure. It was difficult to tell just how much of this material there is, for the beds are not very well exposed, but where the sample was taken the shale is about 2 feet thick. Possibly there are other beds of the same kind within the formation. Strike about N. 40° E.; dip about 50° SW.

Sample **378** came from some fossiliferous beds about 25 feet below the top of the exposure. These beds are underlain by about 3 feet of fine-grained yellowish-brown sandstone, the joint planes of which are coated with a black substance resembling tar or asphalt. The highly fossiliferous beds are not much more than a foot in thickness and grade upward into the dark-brown shale represented in sample 379.

Sample **379** came from a bed of shale about 5 or 6 feet thick overlain by a hard bed of fine-grained sandstone. Near the middle of the shale bed are calcareous lenses containing shells and coatings of tar or asphalt.

Samples **380** and **381** came from the E. ½ sec. 32, T. 14 N., R. 2 E., near the head of the central branch of the north fork of Freeman Creek. At this point there is a landslide exposing the shale. The beds are so closely folded here that it is difficult to tell how much shale is present, but it is believed that at least 30 feet of shale is exposed. Sample 381 was taken near the top of the belt, and sample 380 near the middle. Wherever seen the shale seems to be petroliferous, in that it gives off a very distinct odor of petroleum when fragments are rubbed together. The beds appear to have a general anticlinal structure, the axis passing in a general northwesterly direction at this locality, but the structure is complicated by minor folds. Without knowing the details of the structure, the writer suspects that samples 380 and 381 probably came from beds higher in the section than samples 377 and 379.

Sample **382** came from a prospect pit on the west fork of Crooked Creek, in sec. 36, T. 14 N., R. 1 E. From its relation to the overlying belt of white limestone, the shale is regarded as a part of the same belt as that at the head of Freeman Creek (samples 377–381). The prospect appears to be at the crest of an anticline, whose axis trends nearly due east. The beds dip steeply away from the opening on both the north and south sides. Above the shale on each side of the prospect is reddish-brown sandstone, overlain by gray limestone. The total thickness of the shale could not be determined, but from all appearances it must be between 30 and 70 feet. The sample represents a thickness of 3 feet exposed in the prospect pit. The shale is not well exposed elsewhere at this point.

Sample **383** was taken on the North Fork of Musselshell River about 4 miles east of Delphine, in T. 9 N., R. 11 E., from black fossiliferous shale in the lower part of the Quadrant formation. The bed sampled is 7 feet thick and is exposed along an irrigation ditch on the north side of the valley. The beds are overturned and dip steeply westward.

Sample **384** was taken on the west side of Ross Peak, in the Bridger Range, in T. 2 N., R. 6 E., from a bed of black shale 2½ feet thick, probably of Quadrant age, lying between quartzitic sandstone layers.

Samples **385** and **386** came from a point half a mile northwest of Lombard station, along the Northern Pacific Railway, in the Missouri River valley in T. 4 N., R. 2 E. Here the lower part of the Quadrant formation contains much black shale and shaly limestone in which prospect pits have been dug for coal. Some of the rock when freshly broken emits an oil odor. Neither of the samples on distillation gave any oil. About half a mile northwest of the Quadrant exposures is an abandoned coal mine in the Kootenai formation.

THREEFORKS AND OTHER FORMATIONS.

The Threeforks formation is exposed at several places in west-central Montana. Samples from this and other formations were obtained as described below. Some other exposures were visited but not sampled.

Samples **387** and **388** were obtained on the south side of Jefferson River at the east end of the canyon, about 4 miles east of Jefferson station, where nearly vertical and considerably sheared black shales of the Threeforks formation contain a layer of coal several inches thick along which a shaft was sunk to a depth of more than 30 feet many years ago. Sample 387 was taken from the weathered coal near the outcrop; sample 388 represents hard pieces of coal picked from the dump.

Sample **389** was taken in the bottom of a small ravine 4 miles N. 20° W. of Logan, in T. 2 N., R. 2 E., at the bottom of a prospect pit, 20 feet beneath the surface, in soft dark-brown shale 3 feet thick dipping 40° N. This shale, which is of Threeforks age, is separated from the Madison limestone by 30 feet of shaly sandstone.

Samples **390** and **391** were collected from the Threeforks formation at the west side of Ross Peak, in the Bridger Range, in T. 2 N., R. 6 E., at an elevation of about 7,700 feet. The section at this locality is as follows:

Geologic section on west side of Ross Peak, Mont.

	Ft.	in.
Madison limestone, in thin platy layers.		
Threeforks formation:		
Shale, black, tough; emits oil odor when freshly broken (sample 390)	2	6
Sandstone, shaly, calcareous and fossiliferous in lower portion	30	
Shale, black; emits oil odor when freshly broken (sample 391)	10	
Shale, sandy, unmeasured.		

Sample **392** represents a coal bed of Cretaceous age in the railroad cut at Chestnut station, 7 miles east of Bozeman.[13] In the same vicinity are abandoned coal mines. The thickness of the beds sampled is about 10 feet, including coal and black shale and excluding a layer of gray shale 1½ feet thick near the base.

On the north side of the valley of Sixteenmile Creek, along the Chicago, Milwaukee & St. Paul Railway about 2 miles east of Lombard, there are complete exposures of the upper half of the Threeforks formation, consisting of greenish to dark-gray shaly sandstone and sandy shale but including no beds of promising appearance as oil shale.

[13] For a description of the Chestnut district see Calvert, W. R., The Livingston and Trail Creek coal fields, Park, Gallatin, and Sweet Grass counties, Mont.: U. S. Geol. Survey Bull. 471, pp. 384-405, 1912.

In a ravine on the north side of Gallatin River opposite Logan village complete exposures of the Threeforks formation show the following beds, none of which warrant sampling for oil shale:

Section near Logan, Mont.

	Ft.	in.
Madison limestone, in thin layers, unmeasured.		
Threeforks formation:		
Sandstone, dark brown	1	6
Shale, black, sandy	2	
Sandstone, grayish brown, in even layers	25	
Clay shale, dark gray, fragile	11	
Sandstone, shaly, fossiliferous	17	
Limestone, dark gray, fossiliferous	6	
Shale, greenish, grading down into sandstone	30	
	92+	

On the North Fork of Musselshell River near Delphine, in T. 10 N., R. 11 E., a search was made along the outcrop of the Threeforks formation, but no black shale was found.

DILLON-DELL AREA, SOUTHWESTERN MONTANA.

PHOSPHORIA AND ASSOCIATED FORMATIONS.

General geology.—In the Dillon-Dell area the formation of chief interest as a bearer of oil shale is the Phosphoria. This formation also contains phosphate beds which persist northward to the Garrison field, near Helena, and southward through southeastern Idaho into Utah, where the rocks are included in the Park City formation. Although the phosphate beds in the Dillon-Dell area are fairly rich and possibly of minable thickness, they do not compare favorably with the deposits now mined in southeastern Idaho.

From Dillon eastward into Yellowstone Park and the west-central Montana area the Phosphoria beds change in character and the phosphatic black shale member disappears. Throughout the region the Phosphoria shales crop out along the principal mountain fronts and are in general steeply dipping and extensively faulted.[14] The formation has never been completely mapped in the Dillon-Dell area, and detailed mapping in the future should disclose further outcrops, especially in the southern portion of the area, along the Idaho State line.

In the detailed descriptions of beds sampled are given measurements of the phosphatic shale beds and associated phosphate rock, and it is only necessary to give here a general outline of the stratigraphy showing the associated formations.

[14] For a description of the Phosphoria and Quadrant formations in the Threeforks-Yellowstone Park region see U. S. Geol. Survey Prof. Paper 120, pp. 111–121, 1918.

Generalized section of Phosphoria and associated formations in Dillon-Dell area, Mont.

	Feet.
Triassic beds:	
Limestone and sandstone, shaly, generally brownish on weathered surface, containing characteristic fossils including *Lingula*	350
Shale, sandy, yellowish brown; weathers readily to light-yellowish soil	100
Phosphoria formation:	
Quartzite, cherty, grading down into bedded chert alternating with quartzite layers	125–150
Shales, black, containing shale oil, more or less phosphatic, interbedded with thin layers of gray and shaly brown oolitic phosphate	50–75
Quadrant formation:	
Sandstone and impure limestone	75–125
Quartzitic sandstone, equivalent to middle portion of Quadrant quartzite of Yellowstone Park section; estimated thickness	700
Limestone and sandstone with shaly beds, reddish in lower portion and with one or more thin beds of black clay shale (nonpetroliferous); estimated thickness	200
Madison limestone (gray massive beds forming rugged escarpment along principal mountain fronts)	800–1200
Threeforks formation (sandy and more or less carbonaceous; locally a graphitic schist where sheared and affected by intrusive rocks).	

Sections and samples.—The oil, nitrogen, and phosphorus contents of the individual shale samples are shown in the following pages. The detailed measurements of the beds as sampled at the several localities are tabulated on pages 85–87. Supplementary notes are given herewith. Attention is called to the illustrative sections of the shale in figure 2.

Locality 1 (samples **524** and **524A**): Warm Spring Creek, tributary of Ruby River, sec. 15, T. 9 S., R. 3 W. At this point the Phosphoria beds are exposed along the crest of a small anticline that is cut across by Warm Spring Creek. The oil shale here is only 1½ feet thick, and none appears in outcrops along the neighboring mountain front to the east.

Locality 2 (sample **517**): Centennial Mountains, Idaho-Montana State line, sec. 16, T. 14 N., R. 42 E., Idaho. The exposures here are at an elevation of about 9,000 feet and dip gently southward. The total thickness of the carbonaceous shale is only 4 feet.

Locality 3 (samples **393–396**): Daly spur, Oregon Short Line Railroad, sec. 2 (?), T. 9 S., R. 10 W., about 13 miles southwest of Dillon. Considerable prospecting was done here for coal by Marcus Daly 23 years ago. The tunnel, which is still open, cuts across the beds, which strike N. 35° E. and dip 30° NW. The outcrop can readily be traced for about half a mile. To the north and south a distance of about a mile are igneous rocks. The samples compare favorably with those collected about 6 miles to the east, in Smallhorn Canyon.

Locality 4 (samples **403–404**): Smallhorn Canyon, secs. 14 and 23, T. 9 S., R. 9 W. The samples were collected on the property of the Dillon Oil Co., where a retort apparatus has been installed that is said to handle 50 tons of shale a day. It is planned to haul the product in trucks to the railroad. The principal phosphate bed, which is 5½ feet thick, contains a little oil and, although somewhat shaly, shows on analysis 19.85 per cent of P_2O_5. The strike of the beds is approximately N. 15° E. and the dip 30°–40° NW. The outcrop extends southward with no faulting to be seen for a mile or so but is probably interrupted by a fault a short distance north of the edge of sec. 14. The richest shale sample (No. 403), representing a thickness of 5½ feet from the tunnel in sec. 14, gives on distillation 21 gallons of oil to the ton. A sample representing a thickness of 5 feet, from the same tunnel, collected by Bowen, yielded

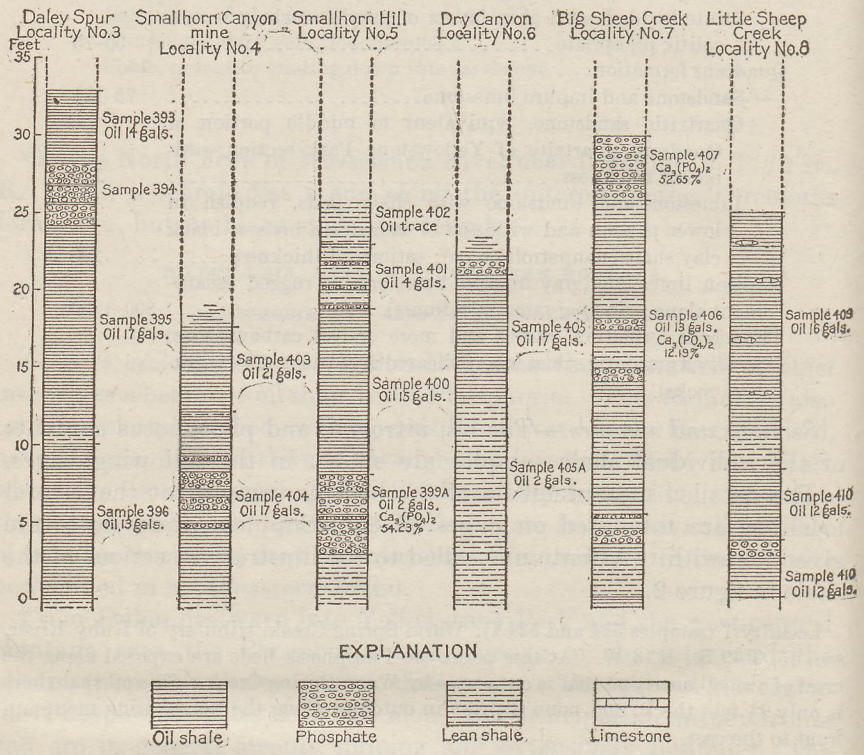


FIGURE 2.—Sections of oil shale and associated phosphate beds in Dillon-Dell area, Mont.

24 gallons to the ton. A small sample selected to include the richest appearing material on the dump gave 30 gallons.

Locality 5 (samples **397–402**): Shallow trench on a hilltop 1 mile south of the tunnel mentioned above (locality 4). Here the shale is weathered, and the results are therefore not representative. The beds, which are completely exposed, show a thickness of nearly 50 feet with the principal phosphate bed a little below the middle.

Locality 6 (samples **405–405A**): Dry Canyon, sec. 12, T. 13 S., R. 10 W., about 3⅜ miles west of Dell station. The beds along the mountain front consist of Triassic limestone and sandstone overturned and dipping under the Phosphoria formation and Quadrant quartzite, which form the higher part of the mountain. The folding, together with more or less faulting, has sheared the black shale so that it is greatly slickensided and resembles coal and as a result has been extensively prospected. All the tunnels are caved in, and the samples were collected in a trench recently dug

in the location of an oil-shale claim. The rock, although comparatively fresh, can hardly be regarded as representative. The richest sample, from 8 feet of shale, gives 17 gallons to the ton. No exposure of the phosphate rock was found.

Locality 7 (samples 406–408): Sheep Creek canyon, T. 13 S., R. 10 W. Years ago a tunnel was dug here for coal on the north side of the valley and about 1,200 feet above it. The beds are for the most part well exposed, and the rock is comparatively unweathered. The structure is complicated, there being one or more large faults in the neighborhood and minor faults that involve the rocks in the tunnel. The beds dip steeply northward and may be overturned. The principal phosphate bed is exposed at the mouth of the tunnel, but its thickness is exaggerated by shearing. The samples were taken in the tunnel. A single hand specimen selected to represent the richest portion of sample 406 gave on distillation 26 gallons of oil to the ton.

Locality 8 (samples 409–411): South Fork of Little Sheep Creek, sec. 4, T. 15 S., R. 9 W. The beds dip 18° W. The samples were collected in a shallow prospect pit dug for coal. Only the lower portion of the shale is represented. It is improbable that the phosphate bed 1½ feet thick is the principal one, although no other was discovered, owing to poor exposures. The shale is considerably weathered and would no doubt give a richer yield if sampled where fresh.

Sections and yield of samples from Phosphoria formation in Dillon-Dell area, Mont.

[Chemical analyses by E. T. Erickson, R. C. Wells, and Benedict Salkover.]

No.	Locality.	Character.	Thickness.	Sample No.	Oil (gallons per ton).	Phosphorus pentoxide (P_2O_5) (per cent).	Nitrogen.	
							Per cent in shale.	Theoretical equivalent in ammonium sulphate (pounds per ton).
			Ft. in.					
1	Warm Spring Creek, sec. 15, T. 9 S., R. 3 W.	Phosphate rock, black, oolitic.	1 8	524				
		Clay	5					
		Shale, black	1 8	524A	3	.....	.....	[a] 7.85
		Shale, sandy, brown.						
2	Idaho-Montana State line, 4 miles southwest of Mount Sautelle, sec. 16, T. 14 N., R. 42 E., Idaho.	Cherty shale	8 0					
		Shale, black, bony	4 0	517	6	.....	.....	[a] 2.09
		Phosphate rock, gray, oolitic.	8					
		Sandstone and shale.						
3	Daly spur, Oregon Short Line R. R., sec. 2 (?), T. 9 S., R. 10 W.; old "coal" prospect tunnel.	Shale, cherty, phosphatic.	9+					
		Shale, dark brown, bony.	4 8	393	14	3.26	0.50	47.1
		Phosphate, dark, oolitic, interbedded with oolitic shale.	4 7	394	.....	19.41	.20	18.9
		Shale, black, bony	14 0	395	17	1.72	.77	72.6
		Shale, brownish gray	1 0					
		Shale, dark brown, bony.	10 0	396	13			
		Lower strata not exposed.						

[a] Ammonium sulphate determined from fixed gas and does not represent the total nitrogen content of the shale.

Sections and yield of samples from Phosphoria formation in Dillon-Dell area, Mont.—Continued.

No.	Locality.	Character.	Thickness.	Sample No.	Oil (gallons per ton).	Phosphorus pentoxide (P_2O_5) (per cent).	Nitrogen.	
							Per cent in shale.	Theoretical equivalent in ammonium sulphate (pounds per ton).
			Ft. in.					
4	Smallhorn Canyon, sec. 14, T. 9 S., R. 9 W.; Dillon Oil Co. property, old "coal" prospect tunnel.	Roof of bony black shale.						
		Shale, hard, bony, black.	5 6	403	21	.....	.63	59.3
		Argillite, soft, phosphatic.	5	404	17			
		Shale, bony	7					
		Argillite, soft, phosphatic.	7					
		Shale, bony	1 8					
		Phosphate rock, gray, oolitic.	3					
		Shale, dark	9					
		Phosphate rock, gray, oolitic, shaly.	1 4					
		Shale, dark	7					
		Phosphate rock, shaly, oolitic.	9					
		Shale, black, soft	1 2					
		Phosphate rock, gray, oolitic.	4					
		Shale, dark, with thin oolitic bands to floor of mine.	4 2					
5	Divide at head of Smallhorn Canyon, sec. 23, T. 9 S., R. 9 W.; prospect trench.	Quartzitic sandstone and chert.	50+					
		Shale, dark, bony in lower part.	10 0	402	Trace.			
		Shale, black, with three layers of phosphate rock, each 4 inches thick.	5 0	401	4	19.20	0.27	25.4
		Shale, black, tough	11 0	400	15	1.68	.53	49.9
		Phosphate rock with three black shaly layers.	5 6	399	2	19.85	.19	17.1
		Shale, brownish gray, phosphatic.	10 0	398	Trace.			
		Shale, brownish gray, slightly phosphatic.	6 0	397	Trace.			
		Sandstone.						
6	Dry Canyon near Dell, sec. 12, T. 13 S., R. 10 W.; prospect trench.	Shale, black, top not exposed.	1+					
		Phosphate rock, oolitic.	1 0					
		Shale, black, soft, greatly slickensided.	8 0	405	17	5.94	.73	68.9
		Shale, brownish black.	10 0	405A	2	.....	.14	13.2
		Limestone	8					
		Shale, sandy, brown	6+					
7	Sheep Creek canyon, T. 13 S., R. 10 W., near old coal prospect tunnel.	Shale	2+					
		Phosphate rock, black, oolitic.	2 5	408	.....	9.34	.22	20.7
		Shale, black, much slickensided.[a]	2 11					
		Sandstone, dark brown.[a]	4					
		Phosphate rock, black, oolitic.	4+					

Sections and yield of samples from Phosphoria formation in Dillon-Dell area, Mont. Continued.

No.	Locality.	Character.	Thickness.	Sample No.	Oil (gallons per ton).	Phosphorus pentoxide (P_2O_5) (per cent).	Nitrogen.	
							Per cent in shale.	Theoretical equivalent in ammonium sulphate (pounds per ton).
			Ft. in.					
7	Section in tunnel at locality 7.	Phosphate rock, oolitic (tunnel mouth).	2+					
		Clay shale[a]	3	407	.....	24.10	.20	18.9
		Phosphate rock, oolitic.	1 3					
		Clay, hard, gritty[a]	1 6					
		Shale, dark brown[a]	5 0					
		Clay shale, gray[a]	1 0					
		Shale, black	8					
		Phosphate rock[a]	1 0					
		Shale, black	1 2					
		Clay, gray, gritty[a]	1 6					
		Phosphate rock, gray[a]	9					
		Shale, black	1 0	406	13	5.58	.68	63.9
		Clay, hard, gritty,[a]	1 3					
		Shale, black	1 0					
		Clay shale, gritty[a]	3 2					
		Shale, black	1 8					
		Phosphate rock	5					
		Clay, hard, gritty	9					
		Phosphate rock, oolitic, black.	1 1					
		Shale, black	1 3					
		Clay, brown, gritty	2 2					
		Shale, black (back end of tunnel).	6					
8	Little Sheep Creek, sec. 4, T. 15 S., R. 9 W.; prospect pit dug for coal.	Shale, bony, black, with limestone concretions.	14 0	409	16	5.57	0.68	63.9
		Clay shale, hard, gritty.	2 6					
		Shale, black, bony	4 0	410	[b] 12	[b] 10.28	[b] 66	[b] 62.2
		Phosphate rock, gray, oolitic.	1 6	411	.....	13.7		
		Shale, hard, black	2 6	410	[b] 12	[b] 10.28	[b] 66	[b] 62.2
		Rocks not exposed	8 0					
		Limestone, not measured.						

[a] Not included in sample. [b] Sample 410 included material from two beds.

TERTIARY FORMATIONS.

Between the principal mountain ranges are broad valleys with rolling topography made up of gently dipping strata of Tertiary age, which contain oil shale. These strata are of moderate extent and were deposited in the basins which they now occupy. The rocks consist of sandy shale, sandstone, impure lignitic coal, brown oil shales, and a considerable amount of shaly to conglomeratic material of volcanic origin. At the base is a conglomerate made up of limestone, shale, sandstone, granite, and quartz pebbles derived from the adjacent mountain slopes.

Figure 3 is a hypothetical cross section of an intermontane basin such as that of Muddy Creek west of Dell, showing the Tertiary beds

of the basin and their probable relation to the older rocks of the surrounding mountains.

The Tertiary shale beds occupy narrow, elongated basins between the mountains. The rocks are diverse in character, and individual layers can not be traced for any considerable distance. In fact, the alternating beds of coarse and fine sandstone, sandy shale, and lignite are just such as one would expect to be deposited in such basins.

The principal belt of these lake beds extends from a point near Bannack, in Grasshopper Valley, south to Horse Prairie and thence up Medicine Lodge Creek, the length of the belt being about 28 miles. Although the beds have not been traced continuously for the entire distance, coal prospect pits are found at numerous places along the belt. Many of these pits reveal either lignite or brown shale, which on distillation yields more or less oil.

The Muddy Creek basin is smaller, being at most only 3 miles wide and about 12 miles long. A well drilled for oil near the center

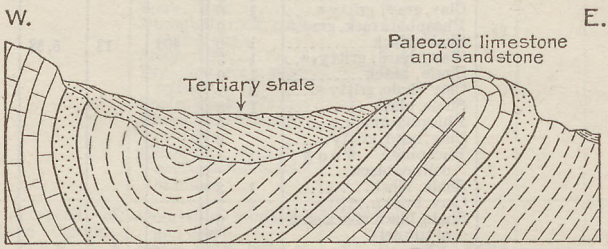


FIGURE 3.—Geologic cross section of a Tertiary basin and surrounding mountains of Paleozoic rocks.

is said to have reached a depth of 1,000 feet without encountering hard rocks, and it seems probable that the bottom of the lake beds was not reached. The supposed relation of the Tertiary beds of Muddy Creek to the underlying older formations is shown by the cross section in figure 3.

The oil shale as exposed in the Muddy Creek basin occurs about the middle of the Tertiary beds. This shale is light brown when fresh and weathers to a cocoa color or nearly white. In the process of weathering the shale breaks up into thin, flexible laminae or flakes resembling manila paper. The richer shale is characterized by a low specific gravity. It contains an abundance of vegetable remains and some well-preserved leaves, chiefly of *Sequoia*. This shale, like that from the Phosphoria formation, will burn when exposed to a strong flame but does not give an odor of petroleum on freshly broken surfaces. On distillation, richer-looking layers as much as 5 feet thick yield about 24 gallons of oil to the ton. Thinner beds occur in other parts of the section, some of which contain thin streaks of ignite. In fact, except for its lighter color, the shale has very much the aspect of an ordinary carbonaceous shale, such as is commonly associated with coal beds. Many of the samples collected along

Medicine Lodge Creek are actually impure lignite, and the richest sample collected in the area (yielding 36 gallons of oil to the ton) comes from such a bed.

At most of the collecting localities described in the following table the samples were taken in old coal prospects, few of which were extended far enough under cover to give unweathered samples. All the samples of lignitic coal, however, may be regarded as fairly representative. No prospecting has been done in the brown shale beds, and the samples were taken from weathered outcrops where the shale has disintegrated to flexible papery layers. It is believed that the same shale well below the surface would prove to be much richer. The outcrop of the brown oil shale is easily recognized, because these beds do not favor the growth of vegetation and as seen from a short distance appear whiter than the associated rocks.

Sections and yield of samples from Tertiary shale in Dillon-Dell area, Mont.

No. on Pl. III, Bull. 711.	Locality.	Character.	Thickness.	Sample No.	Oil (gallons per ton).	Nitrogen.	
						Per cent in shale.	Theoretical equivalent in ammonium sulphate (pounds per ton).
			Ft. in.				
9	Near Grant, sec. 6, T. 10 S., R. 12 W.	Shale, lignitic, bony	1 10	412	3	0.98	92.4
		Sandstone [a]	2				
		Shale, lignitic, bony	1 10	412			
10	Swartz Creek, sec. 26, T. 11 S., R. 12 W.	Shale, sandy	6				
		Shale, bony, brown	3 6	413	1	.74	69.8
		Clay shale.					
11	Medicine Lodge Creek, sec. 30, T. 11 S., R. 11 W.	Coal, lignitic, bony	3	414	1		
		Clay shale, sandy	40				
		Coal, bony, lignitic	1 3				
12	Keystone Creek, sec. 2, T. 12 S., R. 12 W.; coal prospect.	Coal	1 3	415	36	1.02	96.1
		Clay [a]	3				
		Coal	10				
		Clay, sandy [a]	3 8				
		Coal, bony	2 1				
		Clay	4				
	Keystone Creek, sec. 2, T. 12 S., R. 12 W., about 500 feet northeast of coal prospect at locality 12.	Shale, sepia-brown; weathers to flexible paper layers.	3	416	11	.56	52.8
	Keystone Creek, sec. 3, T. 12 S., R. 12 W.; coal prospect near locality 12.	Coal, lignitic, bony	1 4	417	4	.41	38.6
		Clay [a]	3				
		Coal, lignitic, bony	6				
		Clay [a]	6				
		Coal, shaly	2 1				
		Clay [a]	1				
		Coal, shaly	2 8				
		Clay.					
13	Muddy Creek basin, T. 13 S., R. 10 W. (unsurveyed, probably sec. 17); outcrop sampled.	Sandstone.					
		Shale, brown and black, with thin clay bands.	10	418	0		
		Beds not well exposed.	60				
		Shale, brown	3 4	419	4	.13	12.6
		Shale, sepia-brown	2 1	420	24	.20	18.2
		Clay shale	1 3				
		Shale, black	8				
		Shale, sandy [a]	2				
		Shale, black	8	421	4	.35	32.9
		Shale, brown [a]	3 4				
		Shale, black	5				

[a] Not included in samples.

RESULTS OF DISTILLATION TESTS.

The following table includes the results of all the distillation tests on dark shales and carbonaceous materials from the State of Montana. Among the 19 samples of material from the Phosphoria formation the greatest oil yield (24 gallons to the ton) came from a bed 5 feet 6 inches thick near the plant of the Dillon Oil Co. The average of all the samples from this formation was only about 10 gallons to the ton. Tertiary material from one locality (sample 415) gave 36 gallons of oil and showed more than 1 per cent of nitrogen. None of the material from the Upper Cretaceous, the Quadrant, or the Threeforks formation yielded sufficient oil to be of interest, although one sample of shale of the Quadrant formation gave 19 gallons of oil to the ton.

Results of distillation of shale and coal samples from Montana.

Sample No.	Material.	Locality.			Thickness sampled.	Yield of oil per ton of shale.	Nitrogen in shale.	Theoretical equivalent of nitrogen in ammonium sulphate per ton of shale.
		Section.	Township.	Range.				
					Ft. in.	*Gallons.*	*Per ct.*	*Pounds.*
204	Shale, Phosphoria formation	11 or 12	9 S.	9 W.	5 6	24	.....	[a]12.019
205	Shale, Tertiary	12?	13?S.	11?W.	3	8	.....	.....
206	Shale, Phosphoria formation	.....	13?S.	10?W.	80	9	.....	.....
207	do	22	9 S.	3 W.	1 8	3	.....	[a]7.852
208	Shale, Colorado shale	29	22 N.	8 W.	15–20	1	.....	[a]2.080
209	do	9	24 N.	8 W.	6	1½	.....	[a]3.723
210	do	9	24 N.	8 W.	25	2	.....	[a]5.088
211	do	9	24 N.	8 W.	25	2	.....	[a]3.514
212	do	29	22 N.	8 W.	3±	Trace.	.....	[a]2.172
377	Shale, Quadrant formation	28–33	14 N.	2 E.	2	4	0.17	16
378	do	28–33	14 N.	2 E.	.....	2	.06	5.6
379	do	28–33	14 N.	2 E.	5–6	4	.22	20.7
380	do	32	14 N.	2 E.	.....	7	.18	16.9
381	do	32	14 N.	2 E.	.....	19	.36	33.9
382	do	36	14 N.	1 E.	3	8	.39	36.7
383	do	.....	.....	.....	7	0	.....	.....
384	do	.....	2 N.	6 E.	2 6	0	.....	.....
385	do	.....	4 N.	2 E.	.....	0	.....	.....
386	do	.....	.....	.....	.....	0	.....	.....
387	Shale, Threeforks formation	.....	.....	.....	.....	0	.....	.....
388	Coal, Threeforks formation	.....	.....	.....	.....	10	.43	40.5
389	Shale, Threeforks formation	.....	2 N.	2 E.	3	0	.....	.....
390	do	.....	2 N.	6 E.	2 6	1	.....	.....
391	do	.....	2 N.	6 E.	10	2	.22	20.6
392	Coal and shale, Cretaceous	.....	.....	.....	10±	12	.22	20.6
393	Shale, Phosphoria formation	2	9 S.	10 W.	4 8	14	.50	47.1
394	do	2?	9 S.	10 W.	4 7	.....	.20	18.9
395	do	2	9 S.	10 W.	14	17	.77	72.6
396	do	2	9 S.	10 W.	10	13	.....	.....
397	do	23	9 S.	9 W.	6	Trace.	.....	.....
398	do	23	9 S.	9 W.	10	Trace.	.....	.....
399	do	23	9 S.	9 W.	5 6	2	.19	17.1
400	do	23	9 S.	9 W.	11	15	.53	49.9
401	do	23	9 S.	9 W.	5	4	.27	25.4
402	do	23	9 S.	9 W.	10	0	.....	.....
403	do	14	9 S.	9 W.	5 6	21	.63	59.3
404	do	14	9 S.	9 W.	12 7	17	.....	.....
405	do	12	13 S.	10 W.	8	17	.73	68.9
405A	do	12	13 S.	10 W.	10	2	.14	13.2
406	do	.....	13 S.	10 W.	11 9	13	.68	63.9
407	do	.....	13 S.	10 W.	2+	.....	.20	18.9
408	do	.....	13 S.	10 W.	6 5	.....	.22	20.7

[a] Ammonium sulphate determined from this gas does not represent complete conversion of all nitrogen in this shale into ammonium sulphate.

Results of distillation of shale and coal samples from Montana—Continued.

Sample No.	Material.	Locality.			Thickness sampled.	Yield of oil per ton of shale.	Nitrogen in shale.	Theoretical equivalent of nitrogen in ammonium sulphate per ton of shale.
		Section.	Township.	Range.				
					Ft. in.	*Gallons.*	*Per ct.*	*Pounds.*
409	Shale, Phosphoria formation	4	15 S.	9 W.	14	16	.68	63.9
410	do	4	15 S.	9 W.	6 6	12	.66	62.2
411	do	4	15 S.	9 W.	1 6			
412	Coal, Tertiary	6	10 S.	12 W.	3 8	3	.98	92.4
413	Shale, Tertiary	26	11 S.	12 W.	9 6	1	.74	69.8
414	do	30	11 S.	11 W.	3	1		
415	do	2	12 S.	12 W.	8 2	36	1.02	96.1
416	do	2	12 S.	12 W.	3	11	.56	52.8
417	do	3	12 S.	12 W.	6 7	4	.41	38.6
418	do	17	13 S.	10 W.	10	0		
419	do	17	13 S.	10 W.	3 4	4	.13	12.2
420	do	17	13 S.	10 W.	2 1	24	.20	18.9
421	do	17	13 S.	10 W.	2 11	4	.35	32.9

DEVELOPMENTS.

The one serious attempt to commercialize the oil shales of Montana was made by the Dillon Oil Co., which early in 1919 installed a small plant (capacity 50 tons daily) in Smallhorn Canyon, 12 miles south of Dillon. This retort, which is of the Galloupe type, was used for test runs during the summer of 1919 but has since been idle practically all the time.

NEVADA.

GENERAL GEOLOGY AND GEOGRAPHY.

The oil shales of northeastern Nevada have been studied in considerable detail by J. P. Buwalda, from whose unpublished report the following data are taken:

Throughout eastern Nevada the geologic formations can conveniently be grouped into two series—a younger aggregate of Tertiary lavas, tuffs, lake beds, and terrestrial strata (including the rich oil shales of Elko) and an older group consisting of pre-Cretaceous sedimentary formations, principally marine, which have been extensively invaded in some areas by igneous rocks. Between these two series there is a marked unconformity. Most of the valleys and depressions of the Elko region are occupied by younger rocks; the mountain ranges are commonly made up of the more resistant Paleozoic sedimentary strata and the relatively resistant lavas that unconformably overlie them. The oil shales of northeastern Nevada occur in the lower part of the Tertiary section and have been tentatively correlated with the Eocene Green River formation of southwestern Wyoming, northeastern Utah, and northwestern Colorado.[14a]

[14a] Since the above paragraph was written Mr. Buwalda has discovered mammalian remains in beds northwest of Elko which are apparently the equivalent of the oil shales at Elko. The fossils represent middle or upper Miocene time and probably indicate that the strata at Elko are of Miocene age.

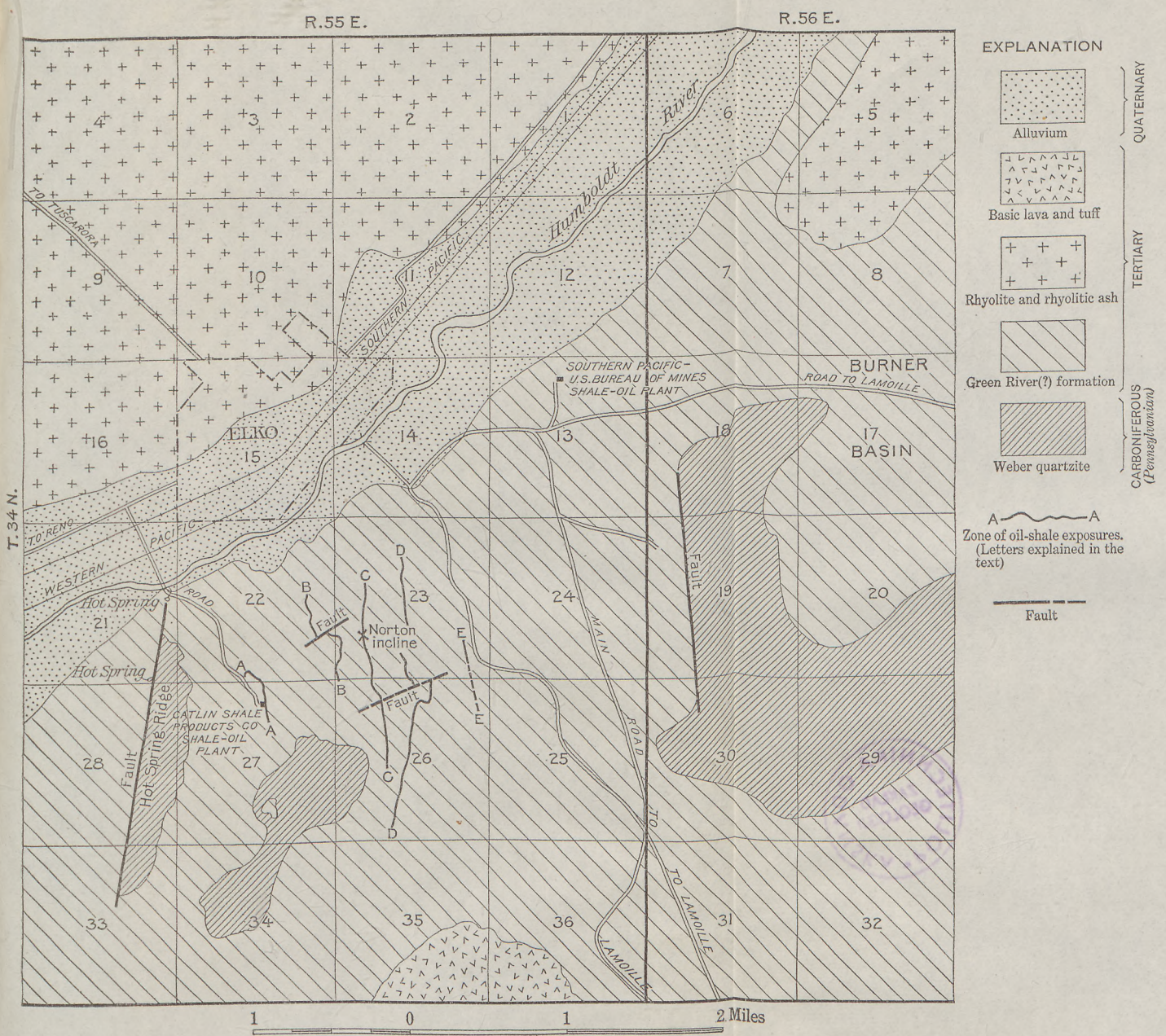
In the territory surrounding Elko (see Pl. XIV) the Green River (?) formation occupies an elongate area parallel to Humboldt River along its southeast side. The exposures extend from the edge of the river flood plain practically to the summit portions of the Elko Range, and at one or two localities, as where the main Lamoille road crosses the range, the beds extend an undetermined distance beyond the crest. To the southwest the strata disappear under Quaternary deposits not far beyond the southwest corner of the township in which Elko is situated. To the northeast the beds extend along the river plain to about the north line of the township, but to the east they fill Burner Basin and reach across the summit of the Elko Range and northward along its east side for a short distance. As shown on Plate XIV, the area of these beds is interrupted by outcrops of older rocks that have been in part brought up by faulting and by outcrops of younger rocks that overlie the Green River (?) formation. In the tract southeast of Elko the total area of the Green River (?) exposures is probably 30 to 35 square miles.

STRATIGRAPHY.

The Green River (?) formation in the Elko region consists predominantly of light-colored shales and sandstones. Conglomerate, limestone, chert, rhyolite, tuff, and bituminous and lignitic shales are interbedded with the sandstone and shale members, and rhyolite intrudes the strata. Shales are perhaps somewhat more abundant in the lower half of the formation, and conglomerate and coarse tuff beds make up a more notable fraction of the upper part near the Lamoille road.

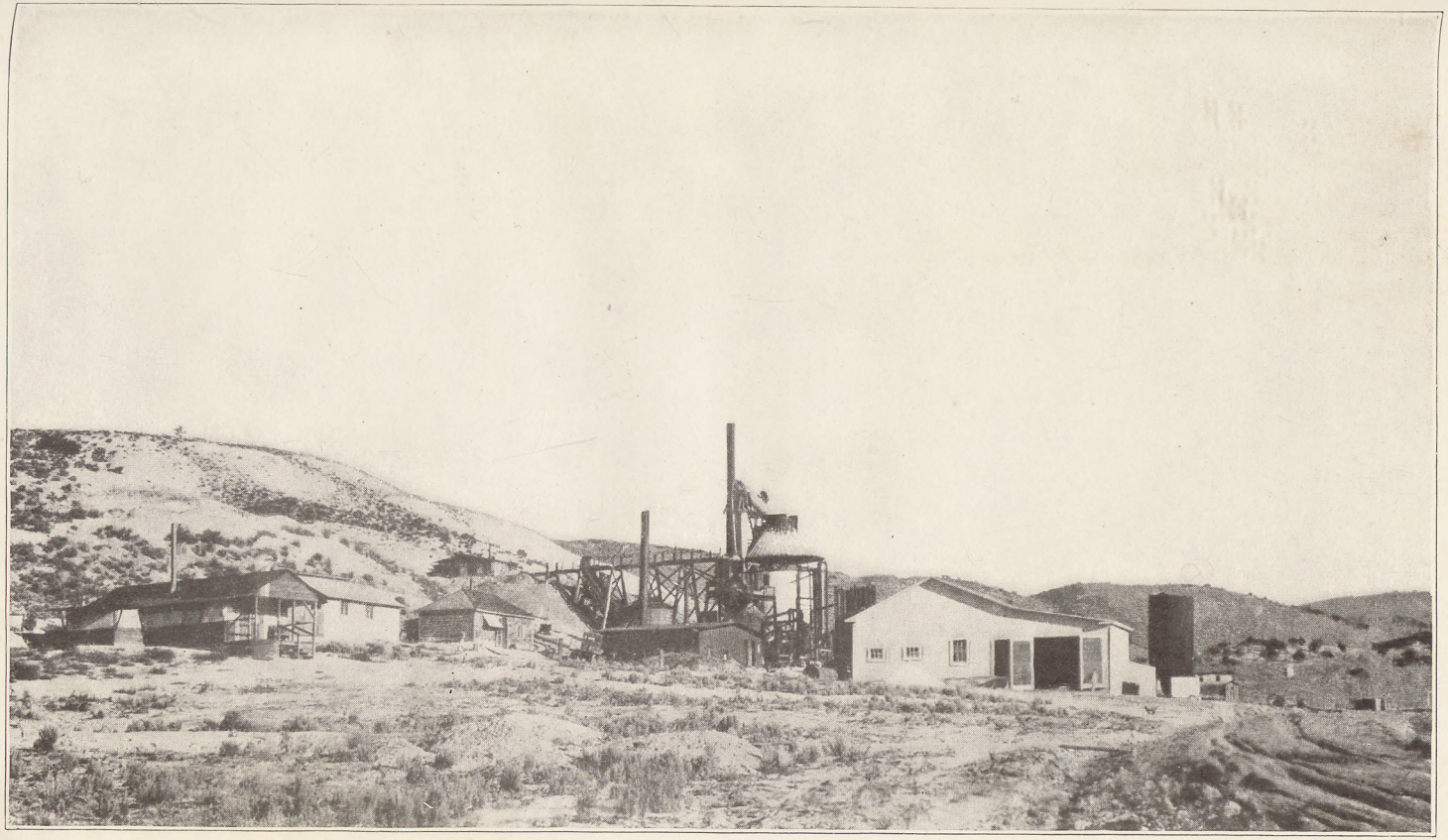
On the whole the rocks are rather soft, but the different members vary considerably. The tuffaceous beds are fairly resistant, and their outcrops commonly form low bluffs, whereas the sandstones and shales weather down readily, and their outcrops between the bluffs are almost invariably mantled with soil. It is hence difficult to find a satisfactory section of the formation.

The shales, which probably form a larger part of the formation than rock of any other type, are in part clean clay shales but are mainly sandy. They usually lack sharp and distinct lamination and are generally interbedded with thin layers of muddy sandstone. In color they are commonly light gray, bluish gray, or brown. Certain hard thinly laminated shales commonly associated with the tuffaceous strata and probably consisting mainly of water-deposited ash are a brilliant white, with fracture surfaces of the plates colored reddish. Some facies of the shales are marly; others are siliceous. Very thinly laminated or paper shales are common at certain horizons, as are also soft brown shales whose relatively dark color and greasy appearance seem to be due to included organic matter. The shale members range from a few feet to a few tens of feet in thickness.



GEOLOGIC MAP OF SMALL AREA SURROUNDING ELKO, NEV.

By J. P. Buwalda.



PLANT OF CATLIN SHALE PRODUCTS CO., ELKO, NEV., IN 1920.

The sandstones, like the shales, are soft and generally not sharply bedded, are commonly muddy, and in color are darker than the shales, ranging through light shades of gray, blue, yellow, and brown. In some of the sandstone strata pebbles are abundant. The sand grains are almost entirely quartz, but clean quartz sand, devoid of mud, is uncommon. The sandstones usually occur as strata a few feet in thickness, rarely more than 20 or 30 feet.

The conglomerate in the Green River (?) formation near Elko has rather unusual characteristics when compared with conglomerates of other Tertiary formations of the Great Basin. The pebbles range from very small ones up to some the size of marbles or large peas, but cobbles are lacking. Almost without exception the pebbles consist of quartz, quartzite, or jasper. The quartzite pebbles are usually black or translucent, bearing black spots or a black surface film. The jasper fragments are commonly green. The pebbles are polished, but most of them still exhibit flattish remnants of fracture surfaces; they are not perfectly rounded. The matrix of the conglomerate is usually white or yellow quartz sand, but in places it is muddy material. Locally, as in the quarry about 2½ miles due south of Elko, the rock is hard enough to be used for building. The conglomerate beds in the lower part of the section are generally not more than a few feet in thickness, but the beds at the higher horizons, as near the main Lamoille road, attain thicknesses of 15 to 25 feet and are in some places much coarser.

Limestone of varying degrees of purity occurs at numerous horizons, usually in beds not over 6 or 8 feet thick. The beds are gray or yellow, are not laminated, and in places are fissile, and locally they have rather irregular lower and upper surfaces. They are generally impure, ranging from sandy or muddy limestone to calcareous sandstone and marl.

Rhyolitic tuffs, which give rise to low bluffs because of their superior resistance to erosion, occur in the section with a certain degree of regularity. They commonly but not invariably overlie the oil-shale zones, which in several places are exposed in bluffs capped by the tuff. The ashy strata are of a brilliant white color and very hard. At some localities they are distinctly stratified as beds of clean ash a few inches to a foot or two in thickness.

Lignite beds occur at several horizons in the Green River (?) formation. The lignite is a light-brown loosely bound material which can usually be crushed in the hands. It has the appearance of slightly compressed plant remains and is still markedly laminated. The lignite beds are as a rule not more than a few inches thick. Adjacent shales are in places darkened with organic matter for considerable thicknesses. Numerous drifts have been sunk on these strata as well as on the oil shales during the last 50 years, some by

the Central Pacific Railway Co. in the early days, others by private individuals, in the hope of obtaining a good fuel for locomotive and domestic use in this intermountain country, but all without success.

The relation of the Green River (?) formation to the older rocks is well shown along the east side of Hot Spring Ridge, south of Elko, where the strata lie on an eroded surface of the Weber (?) quartzite, here largely conglomerate. The older formation strikes obliquely across the ridge, but the edges of the upturned and eroded Tertiary beds are in general parallel to the ridge. The quartz pebbles in the Green River (?) conglomerate were probably derived almost entirely from the Weber (?) conglomerate.

It is probable that at least a large part of the Green River (?) formation at Elko was deposited in a fresh-water lake, as is indicated by the distinct lamination of many of the shale and ash members and some of the sandstones and conglomerates. The alternation of offshore and beach deposits suggests frequent changes in the position of the shore lines of the water body, or changes in the surrounding topography. These changes may have resulted from local earth movements or from changes in the level of the lake. The Elko area seems to have been in the marginal zone of the lake basin or in the midst of islands.

Although gypsum is found sparingly in some of the strata and limestone is not uncommon, there appears to be no reason for believing that the lake was commonly brackish or highly saline. Characteristic arid-climate deposits, such as playa lake beds or angular fanglomerates, were not recognized in the section. Leaves, lignite, and petrified logs attest abundant vegetable growth at times and, with the lake deposits, indicate a climate at least fairly humid.

STRUCTURE.

The Green River (?) formation has been deformed to a moderate degree. In the main area the strata dip east almost throughout the section and strike approximately north. At their base on the east flank of Hot Spring Ridge they dip away from the older strata at an average angle of 30°. Between this ridge and the Catlin shale-oil plant the dip flattens and at one locality is west, but at the plant the beds dip east again at an angle of about 20°. From this point eastward for about 3 miles to the north-south ridge of Weber (?) conglomerate lying west of Burner Basin the dip continues to be east, with certain local and minor exceptions. The angle of dip varies rather irregularly both across and along the strike, and it is clear that the formation was considerably warped and faulted as well as tilted. The general dip is eastward for the whole $3\frac{1}{4}$ miles and ranges in general from a few degrees to 70°; at exceptional localities the strata stand vertical. The Green River (?) strata in most places dip away from

outcrops of Weber (?) conglomerate at considerable angles where the contact is depositional.

The degree to which faulting has affected the Green River (?) strata in the main area is a rather important question, because it affects the determination of the thickness of the formation, and if the faults can be definitely proved, certain underground limits for the oil-shale beds would be indicated. That faulting has occurred is certain, but to determine its extent is difficult. Hot Spring Ridge was created by a north-south fault along its western base by which a block of Weber (?) conglomerate with the overlying Green River (?) beds was tilted eastward. Unfortunately the strata on the downthrown block are not well exposed. A similar north-south fault limits in part the eastern extension of the main area of Green River (?) strata and separates the strata from the Weber (?) conglomerate of the narrow north-south ridge that lies about 3 miles southeast of Elko. The western slope of this ridge is steep, and the Green River (?) strata along its base lie approximately horizontal at some points and dip at low angle toward the older rocks at others. Both this fault and the Hot Spring Ridge fault appear to be of normal type, although conclusive evidence on this point was not noted.

After working over the area carefully Mr. Buwalda concludes that the strata are in essentially normal sequence, with the older beds exposed on the west and the younger beds on the east, and that they are not cut by parallel strike faults into several blocks, each tilted eastward, as was thought after preliminary studies. Although it is believed that strike faulting on the widespread scale suggested has not affected the area, evidence of a certain amount of faulting, both parallel to and across the strike, was observed.

A hasty view of the area suggests that the detailed structure of the Green River (?) formation should be easily and clearly discernible, but a thin mantle of soil covers most of the rock surface between the prominent ridges, and outcrops for determining the attitude, nature, thickness, and succession of strata are lacking over considerable areas. The hills and ridges are very regular in alinement, trending north and south, and represent the outcropping edges of resistant eastward-dipping strata. These ridges are spaced on an average one-fourth to one-third mile apart, and many of them persist for 2 or 3 miles. Their western face is usually steep, and the eastern face long and gentle. The best outcrops of oil shale occur in the steep west faces of these ridges, although all the faces do not show oil shale. The back slopes of the ridges and the interridge areas are somewhat darker in color than the steep western faces, owing to the more somber shades of the shales, sandstones, and conglomerates that underlie them, and also because these rocks are more weathered than the materials in the recently exposed western faces.

In the southeastern part of the SE. ¼ sec. 22, T. 34 N., R. 55 E., a fault of probably normal type but unknown displacement is shown in the walls at the west end of a trench. The fault plane dips 40° W. and strikes N. 20° E. The strata, which are conglomeratic at this point, dip 15° E. Several hundred feet to the north of this locality, along the west slope of a prominent white ridge, slickensides are common and fracturing has probably occurred.

Between these two localities and at the south end of the white ridge a cross fault is shown. Its displacement was not precisely determined because of lack of good exposures to the west, but its strike is approximately N. 60° E. Evidence of similar fracturing was noted at a number of localities, and the formation is doubtless traversed to some extent by undiscovered strike, dip, and oblique faults, the recognition of which is rendered difficult through the general similarity of the strata and the common mantle of soil. In general the strata dip moderately in one direction throughout the section.

In Burner Basin the Green River (?) beds do not continue the constant eastward dip which they have in the main area but slope in various directions, especially in the exposures about the rim of the basin. They have been somewhat folded and apparently disturbed considerably by faulting, a condition most noticeable in the northern part of the basin. In the central and eastern parts low easterly dips predominate.

Because a fault, with upthrow on the east, passes between the beds in the main area and those in Burner Basin, it is not definitely known what portion, if any, of the formation exposed in the main area is represented by the strata in Burner Basin, but as the strata in some parts of the basin appear to lie on the Weber (?) conglomerate it is thought probable that they represent the lower portion of the section in the main area.

RESULTS OF DISTILLATION TESTS.

The Elko oil shales yield from a few gallons to 86.8 gallons or more of oil to the short ton, according to tests made by the Geological Survey. Shale yielding more than 70 gallons does not occur in large quantity, however, being found usually in beds less than 1 foot thick between strata yielding considerably less oil.

Five samples tested from different localities in the Elko field, excluding Burner Basin, representing total thicknesses of beds of 2 feet, 2 feet 3 inches, 2 feet 4 inches, 6 feet 1 inch, and 6 feet 3 inches, yielded by dry distillation, respectively, 62, 60, 50, 50, and 70 gallons of shale oil to the short ton. Representative samples from two beds in Burner Basin at different localities, 6 feet and 10 feet thick, yielded, respectively, 11 and 13 gallons to the short ton.

The following table gives results of tests of oil-shale samples collected in the Elko district:

Results of distillation of samples of oil shale collected in the Elko field, Nev.

[Tested by Dean E. Winchester.]

Sample No.	Location. Sec.	T.	R.	Sampled by—	Thickness.	Weight of shale used in distillation.	Crude oil obtained. Distillation without steam.
					Ft. *in.*	*Ounces.*	*Cubic centimeters.*
132	NE. ¼ 27	34 N.	55 E.	David White	2 4		
6	.....	34 N.	55 E.	D. T. Day	.....	6	62
480	SE. ¼ 8	34 N.	56 E.	D. E. Winchester	10	8½	13
481	SE. ¼ 8	34 N.	56 E.	J. P. Buwalda	6	8½	11
482	NE. ¼ 27	34 N.	55 E.	.....do	6 3	4¼	35
483	SW. ¼ 23	34 N.	55 E.	.....do	6 1	4¼	25
484	NW. ¼ 26	34 N.	55 E.	.....do	2 3	4¼	30
485	NE. ¼ 26	34 N.	55 E.	.....do	2	4¼	31

Sample No.	Yield of oil per short ton of shale.	Gravity of oil at 60° F. Specific gravity.	Baumé.	Yield of gas per short ton of shale.	Yield of ammonium sulphate per short ton of shale.	Remarks.
	Gallons.		°	*Cubic feet.*	*Pounds.*	
132	50.0	0.8449	35.70	.....	4.5	Catlin incline.
6	86.8	.8850	28.2	3,891	6.0	Exact locality not positively known.
480	13.0	.....	.....	.....	16.9	Burner Basin.
481	11.0	.....	.....	.....	15.0	Do.
482	70.0	.....	.....	.....	.....	At portal of Catlin incline.
483	50.0	.....	.....	.....	.....	Norton incline 10 feet from portal.
484	60.0	.....	.....	.....	.....	
485	62.0	.....	.....	.....	.....	

The beds considered most promising because of their thickness (2 feet or more) and obvious richness (50 gallons to the ton of shale) form, however, only a fraction of the oil shale present in the district. The remainder is either much leaner shale or, if rich, occurs in beds too thin and too far separated stratigraphically to make its mining economically feasible. The character and thickness of the shales will be discussed in detail for the different zones of outcrop in a succeeding section.

The quantity of oil yielded by the shales of the Elko region is on the whole not very different from that of the Green River oil shales in Utah, Wyoming, and Colorado. The thickness of both rich and lean shales in this region is much smaller than in eastern Utah or Colorado. It is estimated that there are in the region about 7,219,000 short tons of shale which will yield more than 15 gallons of oil to the ton when distilled. The specific gravity of one sample of this shale yielding 86.8 gallons of oil to the ton of shale was 1.46. This is unusually rich shale, and it is probable that the specific gravity of the shales yielding about 60 gallons is approximately 1.65. The shale testing 86.8 gallons of oil to the ton showed an ash content of 2.29 per cent.

ZONES OF OUTCROP.

The oil shales occur in zones of outcrop that lie at successive horizons and range in thickness from a few feet to about 60 feet. In each zone the beds of oil shale vary greatly in thickness, richness, and other physical features, and by far the greater number of the beds are too thin or too lean to mine. The oil-shale members are interstratified with shale, sandstone, and ash beds, and the total thickness of the nonbituminous and very slightly bituminous beds in any zone commonly exceeds that of the oil shales.

The greatest thickness of good oil shale in a single bed in the Elko field is slightly more than 6 feet. This thickness was observed at two localities—at the Catlin incline, in sec. 27, T. 34 N., R. 55 E., and at the old Norton incline, in sec. 23, about 1,500 feet northeast of the southwest corner of the section. The other beds of rich oil shale are less than 3 feet in thickness, usually only 1 to 2 feet, and nearly everywhere the thin beds of rich shale are separated by too great a thickness of barren shale to make it feasible to attempt mining two or more of them together. As observations on the oil shales are practically limited to artificial exposures, it is possible that beds as promising as those mentioned remain undiscovered, but the extensive prospecting in the field renders this somewhat unlikely.

So far as the data permit generalization, it appears that the detailed stratigraphy in each zone changes rather rapidly from point to point, as openings a few hundred feet apart on such zones as those on which the Catlin incline and the Norton incline were sunk show quite different detailed sections of oil-shale strata. The lack of persistence in the Elko oil shales is, however, not surprising in view of the near-shore and probably highly changeable conditions under which they were deposited.

Zone A.—The lowest stratigraphically of the oil-shale zones of the Elko region, here called zone A, lies mainly in the northwestern part of the NE. ¼ sec. 27 but extends a short distance into sec. 22, T. 34 N., R. 55 E. The outcrop of this zone has a length of about 1,600 feet and terminates abruptly at each end. From the available evidence it is thought to be cut off by cross faulting at the south end and by a rhyolite intrusion at the north end. About 75 feet of beds are exposed in a westward-facing ridge. The richest beds have been uncovered at the portal of the incline that has been driven along the thicker of the beds to a depth of more than 300 feet by the Catlin Shale Products Co. Here the principal bed is 6 feet 3 inches thick, and a second bed above contains 3 feet 8 inches of good shale in the 5 feet 5 inches of strata. Tests of the shale of the Catlin incline gave 50, 70, and 86 gallons of oil to the ton, the yield depending on the thickness and condition of the beds sampled. It was not possible to measure detailed sections of the shale beds either to the north or to the south of the Catlin works, but it is quite certain that to the north, at least, the section changes considerably in its details and that the

most promising beds of the Catlin section do not persist even to the north end of the zone outcrop. At the mouth of the incline the shale beds dip strongly to the east, but the dip decreases rather rapidly down the incline.

Zone B.—The shales of zone B have been exposed in a number of prospect trenches and in one shaft along the west face of a low north-south ridge that extends northward for about half a mile from a point near the southeast corner of sec. 22, T. 34 N., R. 55 E. A fault cuts the outcrop of the zone about midway of its length, and the beds are everywhere so highly contorted and fractured that even if thick, rich shales existed here they would in all probability be of very little value. North of this fault several beds of rich shale are exposed in one small area, but they are too thin to be of interest.

Zone C.—The evidences of oil shale in zone C extend for a little more than a mile through the W. ½ sec. 23 and the W. ½ sec. 25. North of the fault and fracture zone which cuts the outcrop near the north line of sec. 26 the rock series includes several rich shales, but south of the faults the shales are of decidedly inferior quality. At the mouth of the Norton incline, near the middle of the SW. ¼ sec. 23, there are several beds of oil shale, but except for the three at the bottom of the section the beds are too thin to be of value, as is shown in the following section:

Section of beds at the mouth of the Norton incline, near the middle of sec. 23, T. 34 N., R. 55 W., Nev.

	Ft.	in.
Tuffaceous beds, yellowish, platy	50	
Tuffaceous beds, white, yielding small sharp fragments	15	
Shale, siliceous, platy	6	
Oil shale, brown, thin bedded	1	2
Shale, white, hard, tuffaceous	8	
Oil shale, brown, thin bedded	1	
Shale, white	1	4
Oil shale, brown, thin bedded		7
Shale	3	6
Oil shale, brown, papery	2	
Siliceous beds, hard, each about 3 inches thick	1	5
Shale	2	
Oil shale, brown, papery		2
Shale	3	
Oil shale		4
Shale, white, soft; bakes hard on surface	15	
Chert, hard		5
Oil shale, black	1	1
Shale, white, with tinge of brown, thin bedded; contains some bituminous matter; forms roof of incline	3	
Oil shale, dark brown		3
Shale, white with tinge of brown	2	11
Oil shale, black, hard, massive rich	3	2
Oil shale, brown (sample 483; 50 gallons)	1	3
Oil shale, black, hard, massive, dull	1	8
Shale, somewhat carbonaceous, gray	1	6
	125	9

The beds at the mouth of the Norton incline dip eastward at an angle of about 30°, but toward the east they flatten within a short distance.

Zone D.—The outcrop of zone D is by far the most extensive in the Elko field, being traceable for a distance of nearly 2 miles from a point near the south line of sec. 26 in a general northward direction nearly across sec. 23. It passes nearly through the center of each section and, like the outcrop of zone C, is cut into three parts by cross faults. Good exposures are provided in recently opened prospect trenches at several places, especially in the southern part of the zone. In an incline near the quarter corner between secs. 23 and 26 there are two beds of rich shale 2 feet and 15 inches thick, respectively, separated by 2 feet of lean or barren shale. A short distance to the south of this incline there are three beds—two 1 foot thick each and 50 feet below them a third bed 18 inches thick. Still farther south another trench exposes nearly 90 feet of beds in which there are eight thin oil-shale beds, of which the thickest measures 2 feet 3 inches. A sample of this bed gave 62 gallons of oil to the ton on distillation, but its thickness is not sufficient to make it attractive.

The beds along the outcrop of zone D dip generally to the east, although in some places they are nearly horizontal.

Zone E.—Thin but rather rich beds of shale are exposed near the center of the SE. ¼ sec. 23, but their outcrop can not be traced southward unless the slightly bituminous beds in the NE. ¼ sec. 26 are to be considered at approximately the same horizon, but these beds are so unlike the beds to the north that this correlation does not seem probable. In neither of the exposures are there oil shales sufficiently rich or thick to be of interest.

Zone F.—About 700 feet west of the fault that marks the limit of the oil-shale beds of the Elko basin proper, 1,100 feet south and 500 feet east from the northwest corner of sec. 19, T. 34 N., R. 56 E., a prospect was opened in the autumn of 1918 under the direction of D. T. Day. The shale, which occurs as a bed 14 inches thick dipping very slightly toward the fault, was to be used in the retorts of the Scottish type being erected about a mile to the northwest by the Southern Pacific Co. under the supervision of the United States Bureau of Mines. The shale is apparently of good quality, but the bed is thin and probably has but very little extent either along its outcrop or eastward back from its outcrop, being cut off on the east by the fault mentioned above.

Burner Basin.—Separated from the main area of Elko oil shales, in what is known as Burner Basin, is an area of shale beds which somewhat resemble the shales of the main area but are not nearly so rich. Numerous prospect pits and shafts have exposed beds of shale that show on tests as much as 13 gallons of oil to the ton. The two samples

noted in the accompanying table (p. 97) represent thicknesses of 6 and 10 feet, but the shale is too lean to be attractive.

DEVELOPMENTS.

The shales of the Elko region have received their share of attention at the hands of those interested in the development of an oil-shale industry, and even in the seventies, before the true character of oil shales was recognized, attempts were made to utilize the darker of the shales as coal for the railroad. Thirty years ago R. M. Catlin acquired a tract of shale land which he still holds, and since that time he has devoted considerable time and money in attempting to solve the problem of extracting the valuable constituents of the oil shales. After years of laboratory investigations, both at Franklin, N. J., and at Elko, the Catlin Shale Products Co., of which Mr. Catlin is the controlling member, began in the summer of 1916 the installation of the first large-scale shale retort south of Elko, and in 1918, even before the first plant had been given a thorough test, began to assemble the material for a second plant of entirely different design. The retorts of the first plant consisted of four inclined tubes through which the shale was driven upward by auger-like propellers, one in each tube. The tubes were heated from without, and the oil vapors were drawn off at the lower end of the retort. A considerable amount of oil was manufactured in this plant, but its operation was not entirely satisfactory, and it was therefore dismantled. The second retort, working on a different principle, was completed in 1919 and has since that time been given a rather complete trial. Up to January 1, 1920, it is reported to have produced about 15,000 gallons of shale oil, but Mr. Catlin did not yet regard his plant, though of commercial size, as beyond the experimental stage. (See Pl. XV.)

In the summer of 1918 the Southern Pacific Co. began the erection, under the supervision of the United States Bureau of Mines, of an 18-ton plant modeled after the type most used in Scotland. The plant consists of a battery of four vertical tubes, each about 30 feet tall, into the top of which the fresh shale is fed continuously; the spent shale is removed from the bottom. Heat is applied externally in such a way that the temperature of the shale is gradually increased as the shale passes downward in the retort. The plant was completed in 1919, and several test runs were made before cold weather set in, but the plant was then shut down, largely because of the lack of shale upon which to operate.

In regard to the future possibilities of the Elko region, Mr. Buwalda makes the following statement:

> The writer's conclusion, after a survey of the deposits, is that the possibilities of supporting an oil-shale industry in the Elko field are very slight. Although oil shale crops out at many points, only two beds of sufficient thickness to justify mining were

found. These are in secs. 27 and 23, both of which are controlled by the Catlin Shale Products Co. These seams probably contain sufficient oil shale to support a fair-sized plant for a considerable number of years, but it should be recognized that, relatively speaking, they contain a very small amount of shale as compared to the much thicker seams underlying hundreds of square miles in the Uinta Basin, in Utah and northwestern Colorado.

UTAH.

GENERAL FEATURES.

In Utah carbonaceous materials from geologic formations ranging in age from Mississippian to Eocene (Green River) have been examined, but the only shales that are sufficiently rich and extensive to be of economic interest as a source of oil are those occurring in the Green River formation in the Uinta Basin, in the northeastern part of the State.

In general the shales of this region are richest and thickest near the east line of the State, but rich beds of oil shale have been traced almost continuously along the southern rim of the basin to Soldier Summit. Any estimate of the amount of shale present in the basin must be based upon arbitrary assumptions as to the northern limit of the shales and the value of the shale beds beneath a cover of more recent rocks. It is estimated that the basin contains at least 92,159,000,000 tons of shale which will yield as much as 15 gallons of oil to the ton when distilled. In commercial practice it may be possible to recover 60 per cent of this tonnage, although, because of the several unknown factors involved, it may be safer to suggest that perhaps 40 per cent may be recovered.

GEOGRAPHY.

The Uinta Basin, which contains practically all the valuable oil shale of Utah, is a topographic as well as a structural basin, bounded on the north by the Uinta Mountain uplift, on the south by the southward-facing Roan Cliffs, on the west by the Wasatch Mountains, and on the east by the Rangely dome and related structural features in northwestern Colorado. The oil shales of the Green River formation are exposed along the south side of the basin but are covered by younger rocks along the north side. The map (Pl. XVI, in pocket) shows only an area 40 miles wide and 125 miles long on the south side of the Uinta Basin where it was possible to study the shales.

The area examined is one of extensive northward-sloping plateaus cut by many vertical-walled canyons. (See structure section on Pl. XVI.) The Roan Cliffs, along the southern margin of the basin, south of the outcrop of the oil shale, attain at many places altitudes of more than 9,000 feet above sea level, whereas the valley of Green River, which crosses the area from north to south, is less than 5,000

feet above sea level, the maximum topographic relief of the basin thus being at least 4,000 feet. Green River, which rises far to the north in Wyoming, flows southward, crossing the area examined about 45 miles west of the east line of the State, and is joined near Ouray by White and Duchesne rivers. East of Green River the streams draining the area north of the Roan Cliffs flow northward, joining either White River or Green River; west of Green River most of the canyons lead directly to Green River in a general easterly direction. Willow, Hill, Bitter, and Evacuation creeks occupy narrow canyons in Uinta County east of Green River, and each contains water along its entire course, except Bitter Creek, which is usually dry below the mouth of Sweetwater Creek. South of Ninemile Creek Green River enters Desolation Canyon (see Pl. XVII, *A*) and flows in a general southward direction between nearly vertical walls which increase in height toward the south, so that in the region of the Roan Cliffs they rise 3,000 feet above the river.

The main line of the Denver & Rio Grande Western Railroad skirts the Roan Cliffs on the south, and although it is only a short distance from the limit of the oil-shale beds the railroad is accessible only by roundabout routes, except in the western part of the field, where the shale crops out in the highlands near the track. The main line of the railroad comes within the area shown on the map west of Colton, but a branch line runs to Sunnyside, in T. 14 S., R. 14 E., and the north end of the Uintah Railway, which connects with the Denver & Rio Grande Western Railroad at Mack, Colo., is at Watson, near the Colorado-Utah State line.

Wagon roads are nearly as scarce as railroads. A toll road is maintained between Watson, on the Uintah Railway, and Ouray and Vernal, in the interior of the basin, and there are two other well-kept roads connecting the interior of the basin with the Denver & Rio Grande Western Railroad, to the south. The one from Myton south to the head of Gate Canyon and up Ninemile Canyon to Whitmore Park and thence down Soldier Creek to Price is the older but is at present less used than the road from Duchesne southwestward up Indian Canyon and thence down Willow Creek to Helper. During part of the year considerable travel from the interior of the basin goes westward past Strawberry Valley to Salt Lake City. However, snow prevents the use of this route in the winter.

Except along these three principal roads the trail made by one vehicle is usually almost obliterated by wind and weather before another has cause to follow. The few ranchers who live in the valleys of Hill and Willow creeks get mail twice a week from Ouray by special messenger, usually on horseback, although there is a passable wagon road down each of these streams.

Sheep and cattle raising is the principal industry of the region, although there are small farms along the valleys of Ninemile, Argyle, Willow, and Hill creeks and also along White River near Soldier Summit. North of the area shown on the map, in the interior of the Uinta Basin, is some of the richest agricultural land of the State. The mining of gilsonite and elaterite near Watson, Fort Duchesne, Myton, and Duchesne provides employment for a considerable force of miners, and the coal mines at Sunnyside, Castlegate, and Kenilworth are points of great activity.

GEOLOGY.

PRINCIPAL FEATURES.

The Tertiary rocks that occupy the interior of the Uinta Basin have been subdivided on stratigraphic and paleontologic evidence into four formations—the Wasatch, Green River, Bridger, and Uinta. The Wasatch, the oldest of these formations, consists of coarse sandstones, highly colored shales, and conglomerates, with here and there thin lenses of coal. The Green River, which contains the oil shales, overlies the Wasatch and underlies the Bridger. It includes evenly and thinly bedded gray and white calcareous shale, with some sandstone, oolite, and limestone. The Bridger and Uinta formations comprise irregularly bedded somber-colored clay shale and ferruginous sandstone and are distinguished from each other largely by their different fossil content, each formation being very fossiliferous.

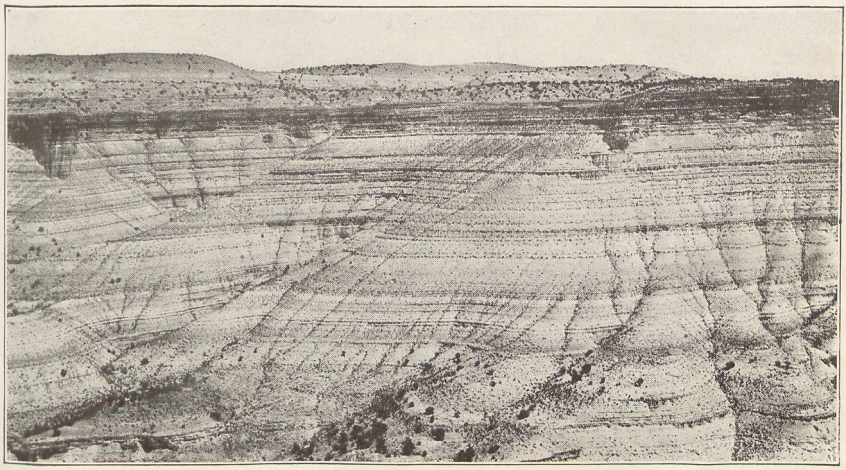
Hydrocarbon materials have been found in all four formations, although bedded deposits (asphaltic sandstone and oil shale) are known only in the Wasatch and Green River. Veins of gilsonite, elaterite, ozokerite, and other related hydrocarbons cut all the Tertiary formations of the Uinta Basin.

WASATCH AND GREEN RIVER FORMATIONS.

The older part of the Tertiary section in the Uinta Basin is represented by a series of conglomerates, conglomeratic sandstones, shale, oolite, limestone, and oil shale, the lower part of which is undoubtedly of Wasatch age, and the upper part, containing the beds of oil shale, is of Green River age. The correlation of the middle part of this series on lithologic evidence is very difficult, especially over broad areas, inasmuch as the individual beds are not persistent and are variable in character, and fossil evidence is lacking. The base of the Wasatch formation has been mapped in several areas around the margin of the basin in Colorado and Utah,[15] and a zone of rich oil shale

[15] Clark, F. R., Coal fields of the Sunnyside and Wellington quadrangles, Utah: U. S. Geol. Survey Bull. — (in preparation). Hancock, E. T., Coal resources of the Meeker quadrangle, Colo.: U. S. Geol. Survey Bull. — (in preparation). Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, 1910. Richardson, G. B., Reconnaissance of the Book Cliffs coal field, Utah: U. S. Geol. Survey Bull. 371, 1909.

A. DESOLATION CANYON, GREEN RIVER, UTAH.



B. OIL SHALE NORTHEAST OF WATSON, UTAH.

Shows thin bedding in this part of the Green River formation. Darker bands are richest beds. About 600 feet of rock exposed.

occurring in the Green River formation has been examined and mapped across the south and east sides of the basin, but the line between the two formations has never been studied. A comparison of the materials in this stratigraphic interval as exhibited in sections studied in northwestern Colorado and northeastern Utah leads to the conclusion that deposition was uninterrupted throughout the time represented by the two formations, although the conditions of deposition varied from place to place.

The irregularity in bedding (see Pl. XVII, *B*) and the coarseness of the beds in the lower part of the series indicate changing local conditions during their deposition, whereas the remarkable persistence and uniformly thin-bedded and fine-grained character of the oil shale indicate stability of conditions. The oil-shale beds were laid down in a great fresh-water lake, the waters of which must have been fairly deep, because much of the fossil material contained in the beds represents a very low order of plant life, which could not have withstood the grinding action of such waves as would have occurred on a lake as extensive as the Uinta Basin (175 miles east to west by 50 miles north to south).

During the field work detailed stratigraphic sections of parts of the Green River formation were measured at points several miles apart along the outcrop of the oil shale, where samples were taken for distillation tests. It was not possible to make careful study of the rocks except at these widely separated localities, hence the correlation of individual beds is not attempted. The examination was sufficient, however, to justify the statement that the principal zone of rich oil shale is the same along the entire southern rim of the basin.

BRIDGER AND UINTA FORMATIONS.

The somber-colored clay shales and coarse sandstones that occupy the interior of the Uinta Basin have been subdivided into two formations—the Bridger and Uinta—on the basis of their fossils. Along the southern margin of the basin the older of the two (the Bridger) rests on the Green River formation without angular unconformity, but along the north side of the basin it overlaps older formations, entirely obscuring the Green River and in most places covering the outcrop of the Wasatch beds. So far as known neither of these formations includes bituminous beds, either oil shale or saturated sandstones.

The southern limit of the Bridger formation was observed at several places during the field work, and the approximate limit of that formation is shown on the map (Pl. XVI, in pocket).

STRUCTURE.

The Uinta Basin is a broad, shallow syncline whose axis trends in a general easterly direction and lies near the north side. The beds dip very gently (1°–2°) toward the center of the basin along its southern margin, more steeply around the west end, and at even greater angles on the north side, along the Uinta Mountains. So far as known the only exception to this general structure is near the head of Hill Creek, where there is evidence of a low dome that causes the outcrop of the oil-shale beds to bend considerably toward the south.

The deformation by which the basin was formed occurred after the deposition of the Green River formation, which contains the oil shale, but before that of the succeeding Bridger formation. There have been other earth movements, however, even since the youngest sedimentary formation (Uinta) of the basin was deposited, as is shown by the presence of great cracks or fissures filled with hydrocarbon material. The origin of these cracks is a disputed question, but the fact that there is neither vertical nor lateral displacement along the fissures and also the fact that their direction bears no consistent relation to the strike of the beds suggest that the cracks are the products of tension, produced perhaps by cooling or drying of the sediments. Where the fissures cut formations that are largely sandstone they present clean-cut walls, but where they cut the beds of oil shale, as near Watson, there is no break filled with hydrocarbon, but the movement was apparently taken up by the shale without fractures.

The deformation of the oil-shale beds of the Uinta Basin is not sufficient, except in very small areas, to hinder materially the mining of the beds of shale by methods used in mining horizontal coal beds, and in many places the surface of the land has the same attitude as the underlying beds and the overburden to the rich shale beds is thin, so that steam-shovel mining can be practiced without difficulty.

STRATIGRAPHIC SECTIONS AND SAMPLES.

The detailed sections given below were measured during the writer's examination of the oil shale in Utah, with the exception of the last five, which were taken by E. G. Woodruff during his investigation in 1913. Beds of shale that are known by testing or are estimated to yield 15 gallons of oil or more to the ton of shale are indicated by heavy type in the sections.

Sections of Green River formation in Utah.

North side of Hells Hole Canyon, sec. 22, T. 10 S., R. 25 E.

	Ft.	in.
Shale, platy, sandy, lean to barren	15	
Shale, mostly lean, with rich beds too thin to sample	11	
Shale, thin, platy (sample 91; 29 gallons)	1	11
Shale, hard, rich (sample 91; 29 gallons)	3	2
Shale, lean (sample 91; 29 gallons)	2	1
Sandstone, persistent		5
Shale, lean, platy, containing one 6-inch bed of rich shale	6	5
Shale, hard, very rich	3	2
Shale, very sandy, lean		11
Shale, hard, rich (sample 90; 45 gallons)	4	8
Shale, hard (sample 89; 17 gallons)	1	3
Shale, soft (sample 89; 17 gallons)	1	4
Shale, hard, rich (sample 89; 17 gallons)	1	5
Shale, lean to barren	1	9
Shale, rich (A) (sample 86, of whole bed, 37 gallons; sample 87, of parts of bed marked "A," 54 gallons; sample 88, of parts of bed marked "B," 25 gallons)		1
Shale, soft (B)		1½
Shale, rich (A)		3½
Shale, soft (B)		3½
Shale, rich (A)		½
Shale, soft (B)		1
Shale, rich (A)		5
Shale, soft (B)		7
Sandstone (discarded)		1
Shale, soft (B)		6
Shale, rich (A)		1
Shale, soft (B)		2
Shale, rich (A)		½
Shale, soft (B)		5
Shale, rich (A)		1½
Shale, lean	1	8
Shale, hard, rich (sample 85; 22 gallons)	1	8
Shale, lean mostly, with rich layers too thin to sample	7	6
Shale, hard, rich (sample 84; 21 gallons)	7	8
Shale, hard, lean to rich, cliff forming	7	4
Sandstone, asphaltic		3
Sandstone, coarse		1½
Shale, hard (sample 83; 8 gallons)	1	
Sandstone (sample 83; 8 gallons)		1
Shale, hard, rich (sample 83; 8 gallons)	2	11
Shale, hard, richest in upper 2 feet (sample 82; 20 gallons)	6	
Sandstone, asphaltic, variable in thickness (same as 22-inch asphaltic sandstone in Temple Switch section; see p. 109)	1	4
Shale, hard, rich (sample 81; 24 gallons)	1	11
Sandstone		1
Shale, sandy, platy, lean to barren	28	
Shale, rich		3
Shale, lean to barren, sandy	2	4
Shale, rich		2
Shale, lean to barren	2	6
Sandstone		1
Shale, gray, lean to barren	18	6
Shale, hard, rich		2

North side of Hells Hole Canyon, sec. 22, T. 10 S., R. 25 E.—Continued.

	Ft.	in.
Shale, gray, lean to barren	2	10
Shale, alternating hard and soft layers (sample 80; 33 gallons)	2	4
Shale, soft (sample 80; 33 gallons)	1	
Shale, alternating hard and soft layers (sample 80; 33 gallons)	1	3
Shale, lean	5	
Shale, rich		1
Shale, papery, or sandy and platy, lean	34	
Shale, rich		10
Shale, sandy, platy, lean to barren	37	
Shale, rich		10
Shale, barren		6
Shale, hard, rich		1
Shale, platy, barren	5	
Shale, hard, rich		2
Shale, for the most part gray and lean, but a few rich layers less than 1 inch thick	85	
Shale, papery, lean	8	
Shale, platy, lean	3	6
Shale, hard, rich		3
Shale, sandy, barren	3	
Shale, hard, rich		2
Shale, thin, platy, lean to barren	30	
Oolite		5
Shale, papery, lean	3	8
Shale, hard, rich		1½
Shale, barren		6
Shale, hard, rich		2
Shale, thin, platy, barren	16	
Oolite		4
Shale, thin, platy, barren	1	2
Sandstone		7
Shale, thin, platy, barren	16	
Cherty layers, distorted, concretionary	1	
Oolite, conglomerate at base	2	4
Shale, gray and drab, barren	2	4
Sandstone		8
Shale, gray and drab, barren	1	10
Sandstone, concretionary	3	6
Shale, gray and drab, barren	20	
Sandstone, with oolitic bands	4	
Oolite	3	9
Shale, gray and drab, barren	23	
Oolite, top distorted and sandy	3	
Sandstone, oolitic	5	
Shale, gray	28	
Sandstone, shaly	15	
Sandstone, massive	4	
Shale, barren, gray, sandy	18	6
Oolite	3	6
Shale, barren, gray, sandy	10	
Oolite	2	
Sandstone	2	
Shale, barren, gray, sandy	65	
Oolite	1	
Sandstone	3	
Shale, gray, lean to barren	19	
Oolite		6
Sandstone, twisted and deformed	1	10

North side of Hells Hole Canyon, sec. 22, T. 10 S., R. 25 E.—Continued.

	Ft.	in.
Oolite	6	6
Shale, gray to drab, barren	19	
Sandstone, massive, yellow	12	6
Shale, gray	5	
Oolitic sandstone	4	
Shale, sandy	13	
Sandstone, massive, yellow, cross-bedded	10	6
Shales, gray and drab, barren	45	
Sandstone, mostly yellow and massive, but with two somewhat shaly zones	41	
Shale, sandy, barren	21	
Shale, rich		6
Shale, gray and drab, barren	35	
Sandstone and barren sandy shale	37	
Shale, largely masked, mostly drab, papery, with sandy zones; not sufficiently cemented to form ledges	95	
Sandstone, coarse, yellow	1	10
Shale, lean to barren, papery	7	
Sandstone, yellowish		6
Shale, soft, sandy (sample 79; 1 gallon)	4	1
Sandstone		3
Shale, masked, but for the most part a barren greenish shale	26	
Sandstone, yellowish brown, poorly cemented	10	
Shales, red and green (Wasatch).		
Total section	1,047	5
Total shale yielding 15 gallons to the ton	56	10
Total shale yielding 30 gallons to the ton	15	8

Sec. 24, T. 11 S., R. 25 E. (part of oil-shale zone.)

	Ft.	in.
Sandstone		8
Shale, lean, sandy	20	
Shale, rich		3
Shale, lean	6	
Shale, rich	1	6
Shale, lean to barren	6	6
Sandstone		5
Shale, lean	4	6
Shale, rich		8
Shale, lean	4	
Shale, rich		10
Shale, lean, papery	1	6
Shale, rich; Shale, soft; **Shale,** rich; Shale, soft; **Shale,** rich (sample 78; 48 gallons).	3 4 4	6 2 17
		8
Shale, lean	2	
Shale, rich	1	
Shale, rich, and papery shale	4	
Shale, medium rich	3	
Shale, rich, hard		2
Shale, lean	4	
Shale, medium rich	9	
Shale, lean	4	
Sandstone, ferruginous		5
Shale, lean to barren	4	6
Shale, hard, rich		6

Sec. 24, T. 11 S., R. 25 E. (part of oil-shale zone)—Continued.

	Ft.	in.
Shale, lean to barren		5
Sandstone, coarse, asphaltic (same as 22-inch asphaltic sandstone in Temple Switch section; see p. 109)	1	1
Total section	91	9
Total shale yielding 15 gallons to the ton	27	2
Total shale yielding 30 gallons to the ton	4	6

North side of Saddle Post Canyon, sec. 22, T. 11 S., R. 25 E. (part of oil-shale zone).

	Ft.	in.
Shale, hard, rich; weathers papery; Shale, rather soft, white on surface, platy (sample 76; 31 gallons).	2 1	11 7
Shale, hard, rich; Shale, white, platy; **Shale,** hard, rich (sample 75; 35 gallons).		10 9 9
Shale, lean to rich; weathers papery	1	6
Shale, lean; weathers white and platy	1	3
Shale, rich; weathers papery		6½
Shale, lean; weathers white and platy	2	4
Shale, hard, rich		10
Shale, lean	12	
Shale, hard, rich		4
Shale, lean, platy	4	8
Sandstone, persistent, quartzitic (identical with 5-inch sandstone in Temple Switch section; see p. 109)		5
Total section	30	8½
Total shale yielding 15 gallons to the ton	10	
Total shale yielding 30 gallons to the ton	8	4

Evacuation Creek between Temple Switch and Dragon.

	Ft.	in.
Shale, thin bedded, lean to barren	40	
Shale, hard, dark (estimated yield, 20 gallons)	1	
Shale, lean to barren, thin bedded; a few rich layers less than 1 inch thick (Diptera larvae)	155	
Sandstone	1	
Shale, platy, lean to barren; two or three rich beds about 1 inch thick	36	
Shale, thin bedded, rich	1	
Shale, lean	6	
Sandstone, persistent		5
Shale, lean, thin bedded	4	
Shale, hard, dark brown, rich	1	10
Shale, hard, light brown, rich	2	1
Shale, hard, dark brown, rich		6
Shale, sandy (not in sample)		2
Shale, hard, dark brown, rich		3
Shale, hard, light brown, rich		10
Shale, hard, dark brown, rich (sample 68; 31 gallons).		8

Evacuation Creek between Temple Switch and Dragon—Continued.

		Ft.	in.
Shale, dark, tough	(sample 67, from richest part of upper bench, 90 gallons; sample 65, from whole bed at surface, 32 gallons).	1	4
Shale, dark, platy		1	5
Shale, hard, dark, rich			2½
Shale, soft, dark brown			3
Shale, hard, dark, rich			3
Shale, soft, dark brown			5
Shale, hard, dark, rich	(sample 66, from whole bed 1½ feet back from outcrop; 55 gallons).		3½
Shale, soft, dark brown		10	
Shale, hard, dark, rich		1	6
Shale, thin bedded, platy	(sample 64; 15 gallons).	4	2
Shale, rather lean and papery		2	
Shale, hard, dark brown to black (sample 63; 32 gallons)		4	3
Shale, hard, lean, some thin sandstone layers		3	10
Shale, hard, rich (samples 58 and 62; 23 and 18 gallons, respectively)		3	11
Shale, minutely banded, some rich layers (sample 61; 10 gallons)		6	7
Shale, lean to barren, with two bands of small dark sandstone lenses		4	
Sandstone, hard, quartzitic, persistent			5
Shale, sandy, barren; thin beds of sandstone		3	1
Shale, brown and black, rich	(sample 60; 12 gallons).		7
Shale, hard; weathers green		1	7
Shale, sandy; weathers greenish gray; lean to barren		2	
Shale, hard (sample 59; 9 gallons)		1	
Sandstone, rough, coarse, containing asphalt; top and bottom surfaces irregular, with shale conforming to the irregularities		1	10
Shale		7	
Sandstone, persistent			3
Shale, lean, sandy, gray to reddish, with several thin layers of sandstone		13	8
Shale, hard, rich	(sample 74; 32 gallons).	2	
Shale, soft		2	
Shale, hard, rich		1	9
Sandstone			3
Shale, hard	(sample 73; 6 gallons).		3½
Sandstone (not included in sample)			1½
Shale, hard		1	7
Sandstone, persistent (not included in sample)			2
Shale, hard			11
Shale, clayey			5
Shale, hard, mostly lean, with thin beds of richer shale		1	6
Sandstone, persistent			3

Evacuation Creek between Temple Switch and Dragon—Continued.

		Ft.	in.
Shale, hard	(sample 72; 7 gallons).	2	9
Sandstone			1
Shale, hard			11
Sandstone			½
Shale, hard		2	6
Sandstone			2
Shale, hard, dark (sample 71; 7 gallons)		7	
Sandstone, persistent			6
Shale, hard, rich to lean	(sample 70; 14 gallons).	3	3
Horizon of sandstone lenses, none of which came where sample was taken.			
Shale, hard, rich		2	6
Sandstone			1
Shale, probably lean.	(sample 69; 19 gallons).		7
Sandstone, bearing gypsum (not included in sample)			5
Shale, hard, dark, rich; some gypsum near top		1	10
Shale, with considerable gypsum			4
Shale, very dark brown, rich			5
Sandstone, brownish, shaly		23	
Shale, papery, lean		1	
Shale, rich; weathers blue			6
Shale, sandy, and barren shaly sandstone		10	
Shale, rich, papery			6
Shale, sandy, barren		17	6
Sandstone, brown, massive			11
Shale, lean to barren		2	6
Sandstone, massive, ledge making		5	
Sandstone, brownish, shaly		50	
Shale, forming ledge, lean to rich		4	6
Shale, papery, lean to barren		4	
Shale, hard, rich			3
Shale, sandy, lean to barren; two or three sandstone ledges less than 1 foot thick		43	
Shale, papery; numerous thin blue rich bands		7	
Shale, barren, with several brownish sandstone layers 2 to 4 inches thick		20	
Shale; weathers bluish; rich, ledge forming		1	
Shale; weathers bluish; barren		2	7
Sandstone, light brown		1	
Shale; weathers bluish; barren		1	5
Sandstone, light brown		4	
Shale; weathers bluish; barren		1	6
Sandstone, light brown			8
Shale; weathers bluish; barren		1	3
Sandstone, massive		2	6
Sandstone, gray, shaly		3	
Sandstone, yellowish brown, not well cemented		48	
Shale, gray		35	
Sandstone		4	
Shale, gray		7	
Sandstone		2	

Evacuation Creek between Temple Switch and Dragon—Continued.

	Ft.	in.
Shale, drab	13	
Oolite	6	
Shale, drab	42	
Oolite	2	4
Shale, gray	4	
Oolite	3	10
Shale, gray	14	6
Sandstone, massive, cross-bedded	14	
Shale, drab	6	
Sandstone, massive	8	6
Shale, gray and drab	28	
Sandstone, resistant		10
Shale, drab	4	
Sandstone, massive	23	
Shale, drab	11	
Sandstone, poorly cemented	4	6
Shale, drab to green	17	
Oolite, much distorted	2	8
Shale, gray	1	
Oolite, much distorted	8	6
Shale, sandy	19	
Oolite	3	
Sandstone, massive	7	
Oolite	1	2
Sandstone, massive for the most part; some oolitic members near base	61	
Shale, drab; upper surface very irregular	4	
Sandstone, massive	8	
Sandstone, shaly	18	
Shale, gray, sandy	7	
Sandstone, yellow, massive	5	6
Shale, gray, sandy	17	
Sandstone, massive	3	
Shale, drab	2	
Sandstone, massive	14	
Shale, drab to dark, sandy and concretionary	5	6
Shale, platy, gray and drab	11	
Oolite		6
Sandstone, finely cross-bedded, poorly cemented	5	
Oolite		10
Sandstone, massive	2	
Shale, drab, sandy	3	10
Sandstone, massive	1	6
Shale, drab	3	3
Sandstone, massive	3	
Shale, gray and drab	102	
Sandstone, minutely cross-bedded		8
Shale, gray and drab	97	
Oolitic sandstone, forming ledge; lower 4 inches conglomeratic and may well be considered basal member of Green River	1	4
Sandstone, yellow, poorly cemented	28	
Shales, red and green, undoubtedly Wasatch.		
Total section	1,306	10½
Total shale yielding 15 gallons to the ton.	57	8
Total shale yielding 30 gallons to the ton.	22	9

South side of ridge in sec. 4, T. 12 S., R. 25 E.

	Ft.	in.
Shale, lean	30+	
Shale, rich		10
Shale, rich (sample 136; 43 gallons)	3	
Sandstone, brown, resistant		2
Shale, fairly rich	1	6
Shale, rich, papery (sample 135; 26 gallons)	3	8
Shale, lean	2	4
Shale, rich (sample 134; 30 gallons)	4	4
Shale, platy, fairly rich (sample 133; 15 gallons)	6	2
Shale, lean	3	6
Sandstone, brown, resistant		5
Shale, lean	5	2
Sandstone, asphaltic, coarse	1	8
Shale, lean	8	
Sandstone, yellow		10
Shale, sandy, lean	33	
Sandstone, massive, yellow (This bed to the west is locally saturated with asphalt.)	20+	
Total section	124+	
Total shale yielding 15 gallons to the ton.	19	6
Total shale yielding 30 gallons to the ton.	7	4

Spring branch of Bitter Creek, about sec. 17, T. 13 S., R. 24 E.

	Ft.	in.
Shale, lean to barren mostly, but with two or three rich bands, each about 3 or 4 inches thick	35+	
Shale, papery (sample 144; 50 gallons)	4	2
Shale, black, rich (sample 143; 23 gallons)	2	
Shale, thin, platy	1	8
Shale, black, very rich (sample 142; 21 gallons)		10
Shale, thin, platy	2	3
Shale, hard, rich, black	1	11
Shale, thin bedded, platy (sample 141; 31 gallons)	1	7
Shale, hard, rich, black		9
Shale, thin bedded, platy (sample 140; 14 gallons)	2	6
Shale, hard, rich, black	1	2
Shale, lean	4	6
Shale, rich, hard (sample 139; 15½ gallons)	4	5
Shale, lean	1	2
Shale, thin bedded (sample 138; 11 gallons)	2	4
Shale, thin bedded (sample 137; 2½ gallons)		8
Sandstone		½
Shale, thin bedded	3	11
Shale, lean	2	6
Shale, rich		6
Shale, lean	3	6
Shale, hard, rich		3
Shale, sandy, and a few thin beds of sandstone, lean to barren	31	
Sandstone, conglomeratic; weathers hackly	2	

Spring branch of Bitter Creek, about sec. 17, T. 13 S., R. 24 E.—Continued.

	Ft.	in.
Shale, sandy, barren	16	
Sandstone, forming weak ledge	4	
Shale, platy, barren	18	6
Sandstone, oolitic, massive, and somewhat conglomeratic	9	
Shale, barren and sandy, with some thin platy sandstone	47	
Sandstone, much contorted and containing large concretionary bodies	3	
Total section	214+	
Total shale yielding 15 gallons to the ton.	22	6
Total shale yielding 30 gallons to the ton.	8	5

Bitter Creek, about sec. 33, T. 12 S., R. 23 E.

	Ft.	in.
Shale, hard	1	3
Shale, hard, rich, thin, platy (sample 146; 38 gallons)	1	10
Sandstone (not sampled)		1
Shale, hard, rich	2	1
Shale, hard, rich (sample 145; 43 gallons)	5	9
Total section	11	
Total shale yielding 30 gallons to the ton.	11	

Willow Creek, about sec. 29, T. 12 S., R. 21 E.

	Ft.	in.
Shale, lean to barren, with four or five rich beds not more than 6 inches thick.	40+	
Shale, papery, forming ledge (sample 150; 28 gallons)	4	
Sandstone		2
Shale, rich beds alternating with sandy lean layers (sample 149; 10 gallons)	4	10
Shale, rich (sample 148; 19 gallons)	1	11
Sandstone		½
Shale	1	
Shale, mostly platy (sample 147; 15 gallons)	5	2
Total section	57+	
Total shale yielding 15 gallons to the ton	8	5

East side of Hill Creek, sec. 7, T. 13 S., R. 20 E.

	Ft.	in.
Shale, lean to barren (estimated)	10	
Sandstone, yellow (estimated)	10	
Shale, lean to barren (estimated)	15	
Shale, rich		6
Shale, lean to barren (estimated)	6	
Sandstone, yellow (estimated)	20	
Shale, lean, grading to sandy shale, barren	4	
Shale, black, rich (sample 153; 20 gallons)	1	
Shale, lean	2	
Shale, brown, lean (sample 152; 14 gallons)	1	2
Shale, black, hard, rich	1	3
Shale, barren		8
Shale, black, hard, rich (sample 151; 36 gallons)	4	11
Total section	76	6
Total shale yielding 15 gallons to the ton.	7	8
Total shale yielding 30 gallons to the ton.	4	11

Spring east of Tabyago Canyon, sec. 16, T. 13 S., R. 19 E.

	Ft.	in.
Shale, papery (sample 156; 31 gallons)	3	6
Shale, massive	2	10
Shale, lean to barren	2	6
Shale, with sandstone concretions		4
Shale, lean (sample 155; 18 gallons)	1	11
Shale, rich	1	9
Shale, papery, lean	2	
Shale, papery, rich		9
Shale, sandy	3	
Shale, lean	1	11
Sandstone		2
Shale	1	7
Shale (sample 154; 9 gallons)	6	
Sandstone	1	11
Shale (estimated yield, 10–15 gallons)	3	4
Total section	33	6
Total shale yielding 15 gallons to the ton.	12	9
Total shale yielding 30 gallons to the ton.	6	4

South of Ninemile Creek, sec. 32, T. 11 S., R. 18 E.

	Ft.	in.
Shale, papery (sample 160; 23 gallons)	1	6
Shale, hard	1	10
Shale, hard	5	10
Sandstone		1
Shale, hard (sample 158; 43 gallons)	3	8
Shale, barren, sandy	28	
Shale, hard (sample 157; 22 gallons)		9
Shale, papery	1	2
Shale, lean	8	
Shale, hard, rich		10
Total section	51	8
Total shale yielding 15 gallons to the ton.	15	7
Total shale yielding 30 gallons to the ton.	3	8

South side of Horse Bench, sec. 14, T. 12 S., R. 17 E.

	Ft.	in.
Sandstone and shale (estimated)	50	
Shale, lean (estimated)	50	
Shale, papery (sample 163; 15 gallons)	3	3
Shale, lean, with some rich beds (estimated)	75	
Sandstone	25	
Shale, lean, with thin beds of rich shale	20	
Sandstone, yellow, massive	4	
Shale, lean	6	
Shale, rich (sample 162; 31½ gallons)	5	2
Sandstone, green	30	
Shale, lean	3	
Shale, rich (sample 161; 16 gallons)	1	8
Sandstone, yellow (not sampled)		1
Shale, moderately rich	1	7
Sandstone, green (not sampled)		1
Shale, lean		4
Sandstone, green (not sampled)		1
Shale, lean		8
Shale, rich	2	8

South side of Horse Bench, sec. 14, T. 12 S., R. 17 E.—Continued.

	Ft.	in.
Shale, lean, papery	3	
Shale, fairly rich	1	
Shale, lean.		
Total section	282	7
Total shale yielding 15 gallons to the ton.	14	4
Total shale yielding 30 gallons to the ton.	5	2

Rock Canyon, 9 miles east of Willow Springs, about sec. 34, T. 14 S., R. 16 E.

	Ft.	in.
Shale, lean.		
Shale, hard, rich; **Shale,** soft, brown, medium; **Shale,** hard, rich; **Shale,** thin, bedded, rich; **Shale,** hard, medium (sample 164; 32 gallons).	1	3
Shale, lean.		
Total shale yielding 30 gallons to the ton.	3	10

East side of Water Canyon, sec. 22, T. 11 S., R. 15 E.

	Ft.	in.
Shale, rich (sample 167; 24 gallons).	3	10
Shale, lean	7	
Shale, brown; **Shale,** rich (sample 166; 13½ gallons).	1	8
Shale, lean to barren	18	
Shale, dark brown (sample 165; 29½ gallons)	3	2
Total section	34	8
Total shale yielding 15 gallons to the ton.	7	

Pete Canyon, sec. 19, T. 11 S., R. 15 E.

	Ft.	in.
Shale, rich (sample 168; 26 gallons).	5	2
Sandstone		1
Shale, barren	20+	
Total section	25+	
Total shale yielding 15 gallons to the ton.	5	2

North side of Avintaquin Creek, sec. 26, T. 6 S., R. 8 W.

	Ft.	in.
Shale and sandstone to top of hill; upper 200 feet is yellow sandy material but contains in upper 100 feet two thin beds (2 inches) of rich oil shale	500+	
Shale, thin bedded, rich (estimated yield, 30 gallons)	1	
Shale and sandstone	75	
Shale, rich (estimated yield, 25 gallons).		10
Shale, lean	7	
Shale, rich (estimated yield, 20 gallons).		5
Shale, barren, and sandstone	300	
Sandstone	10	
Shale, barren (some lean) and sandstone, shaly	260	
Sandstone, white	2	
Shale, lean (estimated yield, 10 gallons).	4	
Shale, barren, and thin beds of sandstone	45	
Shale, thin bedded (estimated yield, 15 gallons)	1	2

North side of Avintaquin Creek, sec. 26, T. 6 S., R. 8 W.—Continued.

	Ft.	in.
Shale, barren	13	
Shale, thin bedded, rich (estimated yield, 25 gallons)	1	
Shale, lean	3	
Shale, thin bedded, rich (estimated yield, 25 gallons)		7
Sandstone, shaly	15	
Sandstone, massive, coarse	2	
Shale, lean to barren	35	
Shale, richer than sample 171	3	
Shale, barren, and sandstone	12	
Shale, sandy	1	
Shale, very lean	17	
Shale, thin bedded, rich (estimated yield, 30 gallons)	1	2
Shale, lean	8	
Shale, thin bedded, rich (sample 171; 32 gallons)	4	
Sandstone		2
Shale, lean	6	
Shale, rich (estimated yield, 20 gallons).		7
Shale, lean	10	
Shale, thin bedded, rich (sample 170; 26 gallons)	2	8
Shale, lean (estimated yield, less than 10 gallons)	2	
Shale, rich (estimated yield, 25 gallons).		6
Shale, lean (estimated yield, less than 10 gallons)	6	
Shale, thin bedded, rich (estimated yield, 25 gallons)		9
Talus to creek, mostly shale	75	
Total section	1,425+	
Total shale yielding 15 gallons to the ton.	17	8
Total shale yielding 30 gallons to the ton.	9	2

Broadway prospect, Dozns Gulch, 6 miles north of Soldier Summit.

	Ft.	in.
Shale, thin bedded	2	3
Covered	20	
Shale, thin bedded (sample 173, lower 6 feet 6 inches; 19 gallons)	12	6
Sandstone		4
Shale, brown; **Shale,** hard, brown; **Shale,** thin bedded (sample 172; 11 gallons at face of drift opening).	3	9
	1	10
	1	6
Shale like above	2	
Talus slope.		
Total section	44	4
Total shale yielding 15 gallons to the ton.	18	1

Kyune Canyon, 4 miles northwest of Colton, about sec. 17, T. 11 S., R. 9 E. (lower shale zone).

	Ft.	in.
Shale, mostly platy (sample 175; 15 gallons)	2	8
Shale, lean and barren	22	
Shale, platy; **Shale,** hard, rich (sample 174; 11 gallons).	4	4
		8
Coal		10
Shale, with thin beds of oil shale	35	
Coal		3
Shale, lean		2

Kyune Canyon, 4 miles northwest of Colton, about sec. 17, T. 11 S., R. 9 E. (lower shale zone)—Con.

	Ft.	in.
Coal		2½
Shale, lean to barren	2	9
Sandstone, massive	4	3
Shale, barren	2	6
Sandstone		6
Shale, mostly barren, with thin rich bands	40	
Total section	126	6½
Total shale yielding 15 gallons to the ton.	3	4

Left Fork of White River, 2 miles north of Soldier Summit, about sec. 18, T. 10 S., R. 8 E. (lower part of formation).

	Ft.	in.
Shale, barren, estimated	300	
Shale, hard, hackly (sample 179; 8 gallons)	3	9
Shale, mostly barren, with two ledges like sample 176	103	
Shale, part papery, part platy (estimated yield, less than 15 gallons)	7	
Shale, not well exposed	140	
Shale, papery (estimated yield, 15 gallons+)	1	3
Shale, barren	4	6
Shale, not well exposed (estimated yield, 15 gallons)	3	8
Shale, barren	4	
Sandstone	1	
Shale, barren	11	
Sandstone	1	10
Shale, barren	3	6
Shale, papery, dirty	3	
Shale, papery, dirty	1	10
Shale, hard (sample 178; 24 gallons).		3
Shale, soft	2	6
Shale, hard	2	4
Shale, twisted and contorted	2	
Sandstone		3
Shale, good as any in sample 178	1	8
Mostly masked but probably barren shales with a few sandstones	155	
Shale, medium rich		6
Mostly masked but probably barren shales with a few beds of sandstone	276	
Shale, soft (sample 177; 7 gallons).		8
Shale, hard	3	6
Shale, barren	12	
Masked, estimated	25	
Shales bearing some oil alternating with sandstones; no minable units	32	
Sandstone		7
Shale, lean to barren		10
Sandstone		5
Shale, possibly rich	8	
Sandstone		2½
Shale, dirty	11	
Sandstone		6
Shale, lean		3
Sandstone		5
Shale, lean		6

Left Fork of White River, 2 miles north of Soldier Summit, about sec. 18, T. 10 S., R. 8 E. (lower part of formation)—Continued.

	Ft.	in.
Shale, soft, dirty		10
Sandstone, cherty (not sampled)		9
Shale, soft		3
Sandstone, cherty (not sampled) (sample 176; 12 gallons).		3½
Shale, hard		4
Shale, soft		5
Shale, rather massive, very fossiliferous	1	3
Shale, soft		5
Shale, rather massive, very fossiliferous (sample 176; 12 gallons)	1	9
Shale, lean, platy	10	
Total section	1,124	2
Total shale yielding 15 gallons to the ton.	21	10

Along Denver & Rio Grande Western Railroad near Old Tucker, sec. 24, T. 10 S., R 6 E.

	Ft.	in.
Shale, massive but not flexible (possibly 15 gallons)	2	8
Shale, lean	4	
Shale, massive but not flexible (possibly 15 gallons)	8	
Shale, lean, gray	28	
Shale, massive, ledge forming, dark colored but not flexible (probably 15 gallons or more)	2	8
Shale, barren	33	
Shale, light brown	4	4
Shale, barren	21	
Sandstone		10
Shale, barren	3	4
Shale, light brown	2	9
Shale, barren	8	
Shale, light brown, forming small ledge (sample 183; 5 gallons)	2	8
Shale, gray, barren	9	
Sandstone, massive	3	10
Shale, gray, barren	25	
Shale, thin plates (sample 182; 14 gallons)	3	6
Sandstone		2
Shale, lean to barren	27	
Shale, dark to light brown (sample 181; 12 gallons)	4	
Shale, lean	1	4
Limestone, very fossiliferous		6
Shale, bluish and grayish (probably none as rich as 15 gallons)	110	
Sandstone	5	
Shale, lean, bluish	6	2
Sandstone	4	6
Shale, lean	10	
Sandstone	2	6
Shale, hard, brownish gray (sample 180; 8 gallons)	3	1
Total section	337	8
Total shale yielding 15 gallons to the ton.	2	8

Sample **185.** Oil shale, collected in sec. 2, T. 18 S., R. 4 E., at top of Wasatch Plateau, San Pete County, from Green River formation (Eocene).

Section of oil shale near head of Manti Canyon, in sec. 2, T. 18 S., R. 4 E.

	Ft.	in.
Shale.		
Shale, thin bedded		7
Sandstone		2
Shale, thin bedded		6
Sandstone		4
Shale, thin bedded		6
Sandstone		2
Shale, thin bedded		3
Sandy limestone.		
	2	6

Sample **186.** Oil shale, collected in Chris Canyon, Juab County, from Green River formation (Eocene).

Section at mouth of old tunnel in Chris Canyon, southeast of Juab, Utah.

	Ft.	in.
Shale, green, barren	1	
Sandstone	1	6
Shale, green, barren		10
Sandstone	1	8
Shale, thin bedded, yellow	1	2
Sandstone		10
Shale (as good as sample 186)	3	6
Shale, lean	3	4
Shale, rich (sample 186; 22 gallons)	2	3
Shale, lean.		
Total section	16	1
Total shale yielding 15 gallons to the ton	5	9

Sample **218.** Cannel coal, collected in Cannel King mine, Kane County, in sec. 26, T. 39 S., R. 9 W., by G. B. Richardson,[16] in 1907; represents a bed 5 feet 6 inches thick. The sample used for distillation had been in a closed glass jar since 1907 and was therefore only slightly weathered.

Sample **474.** Laketown Canyon, 1 mile east of Laketown, Utah, in the NW. ¼ sec. 32, T. 13 N., R. 6 E. Prospect pit in phosphatic brown shale 3 feet thick lying in Mississippian limestone. Result of distillation: Oil, trace.

Sample **475.** "The Oaks" resort, Ogden Canyon, Utah, in T. 6 N., R. 1 E. Black phosphatic calcareous shale in Mississippian limestone outcropping along public road. Bed 3 feet thick sampled. Result of distillation: No oil.

Sample **476.** Carbonaceous shale of Paleozoic age near the summit of the Confusion Range, 15 miles east of Trout Creek, which is near the Utah-Nevada boundary.

Section on east side of Evacuation Creek, at Ute station on Uintah Railway, Utah.

[By E. G. Woodruff.]

	Ft.	in.
Sandstone, brown, calcareous; weathers brown; base of upper member of Green River formation.		
Shale, brown, thin bedded	11	
Limestone, gray, thin bedded	36	
Shale, gray, calcareous	18	
Limestone, gray, thin bedded	6	

[16] Richardson, G. B., The Harmony, Colob, and Kanab coal fields, southern Utah: U. S. Geol. Survey Bull. 341, p. 394, 1909.

Section on east side of Evacuation Creek, at Ute station on Uintah Railway, Utah—Con.

	Ft.	in.
Shale, brown, thin bedded, slightly bituminous (possibly contains 2 or 3 gallons of oil to the ton)	165	
Shale, brown, bituminous		6
Shale, brown, carbonaceous	3	6
Shale, brown, slightly bituminous	1	2
Shale, brown, carbonaceous	3	4
Shale, brown, bituminous		5
Shale, brown, fissile, carbonaceous		5
Shale, brown, bituminous		3
Shale, brown, carbonaceous; weathers gray	62	
Shale, brown, bituminous		8
Shale, brown, carbonaceous; weathers gray	1	4
Shale, bituminous	1	3
Shale, brown, carbonaceous, thin bedded; weathers gray	12	
Shale, brown, bituminous		6
Shale, brown, carbonaceous, with seams of bituminous shale half an inch thick in the lower part; weathers gray	5	
Shale, brown, bituminous	1	10
Shale, brown, carbonaceous	12	
Shale, brown, bituminous; somewhat variable in bitumen content (sample testing 45.2 gallons oil to the ton, collected at Temple station, represents 4 feet of the lower part of this bed)	22	6
Shale, brown, carbonaceous; contains some layers of bituminous shale 1 inch thick	18	6
Sandstone, brown	1	
Shale, brown, fissile	12	
Limestone, brown	1	
Shale, brown, fissile	12	6
Shale, brown, bituminous		8
Shale, brown, fine grained, thin bedded; contains fossil insects; weathers tan	20	
Shale, brown, bituminous		6
Shale, brown, carbonaceous, very fissile; weathers gray	13	
Shale, rusty brown, very sandy, calcareous	40	
Shale, light tan, calcareous; weathers gray	40	
Sandstone, gray, thin bedded in lower two-thirds, thick bedded in upper one-third, locally cross-bedded and ripple marked; weathers rusty	68	
Shale, light brown, in layers as thin as 0.1 inch, slightly carbonaceous; 45 feet above base occurs a bituminous shale seam 4 inches thick, and 6 feet higher another of equal thickness	58	
Shale, bituminous		1
Shale, brown, carbonaceous	1	3
Shale, brown, bituminous		1
Shale, brown, carbonaceous		8
Shale, brown, bituminous		1
Shale, brown, carbonaceous		6
Shale, brown, bituminous (beds sampled; 16 gallons)		2
Shale, brown, carbonaceous		11
Shale, brown, bituminous		2
Shale, brown, carbonaceous		2
Shale, brown, bituminous		2

Section on east side of Evacuation Creek, at Ute station on Uintah Railway, Utah—Con.

	Ft.	in.
Shale, brown, locally slightly bituminous	28	
Shale, brown, bituminous	1	11
Shale, gray, calcareous	4	
Shale, brown, bituminous		4
Limestone, gray		9
Shale, very calcareous	3	
Shale, brown, bituminous		4
Shale, sandy (lower member of Green River formation)	2	
Water in Evacuation Creek.		
	694	5

Section of strata containing bituminous shale beds on north side of White River, Utah, 5 miles east of White River station, T. 9 S., R. 25 E., Salt Lake base and meridian.

[By E. G. Woodruff.]

	Ft.	in.
Shale, gray, fissile.		
Shale, bituminous		9
Shale, brown, slightly carbonaceous		6
Shale, brown, bituminous		2
Shale, brown, carbonaceous	4	
Shale, bituminous		3
Shale, brown, carbonaceous		9
Shale, bituminous		8
Shale, brown, fissile, carbonaceous	2	11
Shale, bituminous	1	
Shale, brown, carbonaceous	1	3
Shale, bituminous (samples test 33.3 and 35.5 gallons)	3	6
Shale, brown, carbonaceous	2	4
Shale, bituminous		6
Shale, brown, carbonaceous	3	2
Shale, bituminous		7
Shale, brown, carbonaceous		10
Shale, bituminous		3
Shale, brown, carbonaceous	4	2
Shale, bituminous (estimated to contain 20 gallons of oil to the ton)	6	10
Shale, brown, carbonaceous		11
Shale, bituminous		9
Shale, brown, carbonaceous.		
	36	1

Section of strata containing bituminous shale on Hill Creek, Utah, in sec. 12, T. 13 S., R. 19 E., Salt Lake base and meridian.

[By E. G. Woodruff.]

	Ft.	in.
Shale, gray, thin bedded.		
Shale, bituminous		8
Shale, brown, carbonaceous	1	7
Shale, brown, thin bedded, calcareous	51	
Shale, bituminous (samples test 16 gallons)		9
Shale, gray, thin bedded	3	
Shale, brown, bituminous (contains 15 gallons of oil to the ton)	1	1
Shale, brown, very sandy	1	1

Section of strata containing bituminous shale on Hill Creek, Utah, in sec. 12, T. 13 S., R. 19 E., Salt Lake base and meridian—Continued.

	Ft.	in.
Shale, bituminous; weathers in thin laminae	5	4
Shale, brown; weathers tan	2	8
Shale, brown, carbonaceous, thin bedded	3	8
Shale, bituminous (estimated to contain 10 gallons of oil to the ton)	1	1
Shale, brown, carbonaceous, thin bedded	4	4
Shale, drab, fissile; weathers gray.		
	76	3

Section of strata containing bituminous shale along freight road from Myton to Price by way of Harper, Utah, 4 miles north of Ninemile Creek, approximately in sec. 12, T. 11 S., R. 16 E., Salt Lake base and meridian.

	Ft.	in.
Shale, thin bedded, olive-green.		
Shale, brown, bituminous		6
Shale, olive-green, sandy	10	
Shale, slightly bituminous; weathers in thin layers (sample yielding 39 gallons to the ton was taken from a 6-inch layer near the top of this bed)	4	10
Shale, brown, carbonaceous		6
Shale, bituminous	1	2
Shale, gray, thin bedded	9	
Shale, brown, slightly bituminous	1	11
Shale, gray, fissile	8	4
Shale, bituminous; weathers fissile (estimated to contain 10 gallons of oil to the ton)	1	2
Shale, gray, sandy	9	
Shale, brown, carbonaceous	5	6
Shale, olive-green, thin bedded	14	
Shale, brown, carbonaceous		6
Shale, gray, very sandy	8	
Shale, brown, carbonaceous		10
Shale, greenish gray, sandy	13	
Sandstone.		
	88	3

RESULTS OF DISTILLATION TESTS.

Of the 96 samples of carbonaceous material from Utah, all but three represent shale from the Green River formation and show yields ranging from a mere trace up to 90 gallons to the ton. The maximum yield was shown by a sample from a thin bed (6 inches thick) near Watson, on the Uintah Railway. More than one-third of the samples show yields of more than 25 gallons to the ton, and most of the leaner samples came from localities where rich beds are present. The percentage of nitrogen was determined in only a small number of samples, inasmuch as most of the samples were tested before it was discovered that the determination of ammonia in the permanent gas did not furnish accurate data for an estimate of the value of the shale as a source of nitrogen compounds.

Results of distillation of shale from Utah.

Sample No.	Locality. Sec.	T.	R.	Thickness of bed sampled.	Gravity of oil at 60° F.[a] Specific.	Baumé.	Yield of oil per ton of shale.	Yield of ammonium sulphate per ton of shale.[a]	Nitrogen in shale.	Theoretical equivalent of nitrogen in ammonium sulphate per ton.	Sulphur in shale.
				Ft. in.		°	*Gallons.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
1	Joab			2 9	0.8995	26.5	11.9	2.5	.....	.....	.....
2	Mt. Pleasant			.....	.8866	27.9	11.9	2.2	.....	.....	.....
3	Tucker			3 0	.6965	26.2	11.9	6.5	.....	.....	.....
4	Soldier Summit			6 3	.8937	26.6	16.8	3.5	0.39	36.7	0.27
58	17	11 S.	25 E.	3 11	.8989	25.74	23	5.04	.....	.....	.....
59	17	11 S.	25 E.	1	.9327	20.10	9	4.59	.....	.....	.....
60	17	11 S.	25 E.	2 2	.9019	25.22	12	4.38	.....	.....	.....
61	17	11 S.	25 E.	6 7	.9014	24.85	10	3.92	.....	.....	.....
62	20	11 S.	25 E.	3 6	.8983	25.85	18	5.37	.....	.....	.....
63	20	11 S.	25 E.	4 3	.8998	25.59	32	6.96	0.53	49.9	0.58
64	20	11 S.	25 E.	6 2	.8870	27.83	15	4.09	.35	32.9	.31
65	20	11 S.	25 E.	6 6	.9090	24.01	32	5.45	.73	68.7	.70
66	20	11 S.	25 E.	6 6	.9052	24.66	55	.....	.80	75.3	.87
67	20	11 S.	25 E.	6	.8745	30.09	90	6.89	1.30	122.4	1.59
68	20	11 S.	25 E.	6 2	.9112	23.64	31	6.99	.70	65.9	.58
69	20	11 S.	25 E.	3 7	.9021	25.19	19	5.04	.32	30.1	.81
70	20	11 S.	25 E.	5 9	.9260	21.18	14	4.98	.....	.....	.....
71	20	11 S.	25 E.	7	.9098	23.88	7	3.48	.....	.....	.....
72	20	11 S.	25 E.	6 3½	.8775	29.54	7	2.25	.....	.....	.....
73	20	11 S.	25 E.	4 8½	.9263	21.13	6	2.61	.....	.....	.....
74	20	11 S.	25 E.	5 9	.8887	27.53	32	7.05	.43	40.5	.42
75	22	11 S.	25 E.	2 4	.9036	24.93	35	5.14	.....	.....	.....
76	22	11 S.	25 E.	4 6	.9034	24.97	31	5.20	.....	.....	.....
77	77	11 S.	25 E.	6 10	.8727	30.42	37	7.81	.68	64.0	.56
78	24	11 S.	25 E.	6 3	.8833	28.49	48	9.76	.....	.....	.....
79	27	10 S.	25 E.	4 1	.....	.....	1	2.11	.....	.....	.....
80	15	10 S.	25 E.	4 7	.9094	23.94	33	5.87	.....	.....	.....
81	15	10 S.	25 E.	1 11	.9073	24.30	24	6.72	.....	.....	.....
82	15	10 S.	25 E.	6	.9163	22.78	20	6.49	.....	.....	.....
83	15	10 S.	25 E.	4	.8975	25.98	8	5.32	.....	.....	.....
84	15	10 S.	25 E.	7 8	.8966	26.14	21	3.77	.....	.....	.....
85	15	10 S.	25 E.	1 8	.8879	27.67	22	5.39	.....	.....	.....
86	15	10 S.	25 E.	3 2½	.8934	26.70	37	6.52	.....	.....	.....
87	15	10 S.	25 E.	1 ½	.8866	27.90	54	5.51	.....	.....	.....
88	15	10 S.	25 E.	2 2	.8914	27.05	25	4.05	.....	.....	.....
89	15	10 S.	25 E.	4	.9059	24.54	17	5.48	.....	.....	.....
90	15	10 S.	25 E.	4 8	.8976	25.97	45	9.22	.....	.....	.....
91	15	10 S.	25 E.	5 1	.8953	26.37	29	5.35	.....	.....	.....
133	4	12 S.	25 E.	6 2	.8920	26.95	15	2.80	.....	.....	.....
134	4	12 S.	25 E.	4 4	.9138	23.20	30	6.98	.....	.....	.....
135	4	12 S.	25 E.	3 8	.9091	24.01	26	4.17	.....	.....	.....
136	4	12 S.	25 E.	3	.9085	24.10	43	6.49	.....	.....	.....
137[b]	Unsurveyed			4 7½	.....	.....	2.5	1.72+	.....	.....	.....
138[b]	.....do			2 4	.9200	22.17	11	1.70+	.....	.....	.....
139[b]	.....do			4 5	.8990	25.72	15.5	2.04+	.....	.....	.....
140[b]	.....do			3 8	.8990	25.72	14	3.05+	.....	.....	.....
141[b]	.....do			4 3	.8986	25.79	31	3.43	.....	.....	.....
142[b]	.....do			3 1	.8960	26.25	21	2.82	.....	.....	.....
143[b]	.....do			3 8	.9200	22.17	23	4.08	.....	.....	.....
144[b]	.....do			4 2	.9060	24.52	50	8.68	.....	.....	.....
145[c]	.....do			5 9	.8912	27.09	43	5.24	.....	.....	.....
146[c]	.....do			5 3	.....	.....	38	5.06	.....	.....	.....
147[d]	.....do			5 2	.8840	28.37	15	2.66	.....	.....	.....
148[d]	.....do			2 11½	.9250	21.35	19	1.81	.....	.....	.....
149[d]	.....do			4 10	.9180	22.50	10	2.16	.....	.....	.....
150[d]	.....do			4	8912.	27.09	28	5.57	.....	.....	.....
151	7	13 S.	20 E.	4 11	.8929	26.79	36	4.46	.....	.....	.....
152	7	13 S.	20 E.	2 5	.....	.....	14	3.48	.....	.....	.....
153	7	13 S.	20 E.	1	.9050	24.69	20	15.92	.....	.....	.....
154	16	13 S.	19 E.	6	.9110	23.67	9	2.49	.....	.....	.....
155	16	13 S.	19 E.	6 5	.8890	27.48	18	2.06	.....	.....	.....
156	16	13 S.	19 E.	3 6	.8850	28.19	31	3.48	.....	.....	.....
157	32	11 S.	18 E.	1 11	.8917	27.00	22+	3.97	.....	.....	.....
158	32	11 S.	18 E.	3 8	.9090	24.01	43	6.41	.....	.....	.....
159	32	11 S.	18 E.	5 10	.8838	28.40	40	6.91	.....	.....	.....
160	32	11 S.	18 E.	3 4	.8780	29.45	23	2.80	.....	.....	.....
161	14	12 S.	17 E.	6 11	.8850	28.19	16	2.85	.....	.....	.....
162	14	12 S.	17 E.	5 2	.....	.....	31.5	4.97	.....	.....	.....
163	14	12 S.	17 E.	3 3	.8890	27.48	15	3.76	.....	.....	.....

[a] Determinations by Bureau of Mines (C. R. Bopp, chemist). Ammonium sulphate determined in permanent gas and does not represent total amount available.

[b] Bitter Creek, 12 miles southwest of Dragon.

[c] Bitter Creek, 15 miles west of Dragon.

[d] Willow Creek, 28 miles west of Dragon.

Results of distillation of shale from Utah—Continued.

Sample No.	Locality. Sec.	T.	R.	Thickness of bed sampled.	Gravity of oil at 60° F. Specific.	Baumé.	Yield of oil per ton of shale.	Yield of ammonium sulphate per ton of shale.	Nitrogen in shale.	Theoretical equivalent of nitrogen in ammonium sulphate per ton.	Sulphur in shale.
				Ft. in.		°	*Gallons.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
164 *e*	Unsurveyed			3 10	.8974	26.00	32	3.55			
165	22	11 S.	15 E.	2 2			29.5	6.71			
166	22	11 S.	15 E.	2 8			13.5	1.49			
167	22	11 S.	15 E.	3 10			24	3.92			
168	19	11 S.	15 E.	5 2	.8866	27.90	26	3.86			
169	12	12 S.	13 E.		.8800	29.09	10	2.23			
170	26	6 S.	8 W.	2 8			26	8.79			
171	26	6 S.	8 W.	4			32	4.96			
172 *f*	Unsurveyed			7 1	.9150	23.00	11	0.29			
173 *f*	do			12 6	.8830	28.55	19	4.39			
174 *g*	do			5	.8890	27.48	11	3.56			
175 *g*	do			2 8	.8980	25.90	15	6.65			
176 *h*	do			5 3	.8640	32.03	12	4.04			
177 *h*	do			4 2	.9100	23.84	7	3.11			
178 *h*	do			6 11	.9050	24.69	24	12.21			
179 *h*	do			3 9	.9220	21.84	8	10.10			
180	24	10 S.	6 E.	3 1	.8900	27.30	8	2.71			
181	24	10 S.	6 E.	4	.8780	29.45	12				
182	24	10 S.	6 E.	3 6	.8590	32.98	14				
183	24	10 S.	6 E.	2 8	.8740	28.18	5				
184 *i*				1 6	.8980	25.90	18.0	3.09			
185	2	18 S.	4 E.	1 10	.8770	30.92	21.0	2.66	2.66		
186 *j*				2 3	.8930	26.72	22.0	2.57	2.77		
218 *k*	26	39 S.	9 W.	5 6			70.0	14.4			
474	32	13 N.	6 E.	3			Trace.				
475 *l*		6 N.	1 E.	3							
476 *m*											

e Rock Canyon, 15 miles east of Sunnyside.
f Doans Gulch, 6 miles north of Soldier Summit.
g Kyune Canyon, 4 miles east of Colton.
h Left Fork of White River 2 miles north of Soldier Summit.
i Three miles north of Fairview.
j Chris Canyon southeast of Juab.
k Cannel coal.
l Ogden Canyon near "The Oaks."
m Near Trout Creek post office.

DEVELOPMENTS.

In Utah there are three points around which oil-shale activities have centered—Salt Lake City, Colton, and Watson. In addition lands in nearly every part of the State known to contain oil-yielding shale have been surveyed, staked, examined, and covered with such so-called development or assessment work as was thought necessary to meet the requirements of the laws relating to mining claims. Assessment work consists in digging prospect pits along the shale outcrop, building roads, trails, and houses to be used in the development of the oil shale, and in some places the construction of tramways, etc. Such evidences of the oil-shale industry are to be found in great abundance, especially along the southern rim of the Uinta Basin.

At Salt Lake City considerable chemical and engineering research has been carried on by representatives of both the University of Utah and the United States Bureau of Mines. Perhaps the first experi-

mental plant was erected by J. B. Jenson, who as early as 1918 had in operation a 25-ton plant of his own design. The retorts of this plant consisted of three horizontal tubes arranged one above another in such a way that the shale which was fed into the upper tube was carried by screw conveyor through each tube and delivered to the tube below and finally discharged as spent shale from the lowest tube. Heat was applied to the tubes externally, so that as the shale proceeded through the apparatus it was subjected to successively higher temperatures. The vapors were removed at different places along the tubes and condensed separately, and at least theoretically there was a partial fractionation of the products of distillation as they were produced. Recently this plant has been used by the chemists and engineers of the United States Bureau of Mines as an experimental laboratory, and the results of tests and experiments made there should be of great value to the industry.

In 1918 a retort designed by Otto Stahlman was set up at the University of Utah, and experimental runs were made, but the writer has seen no published results of these tests, nor is there any information available as to the use of the plant since that year.

The oil shale near Colton has attracted considerable attention because of its nearness to the main line of the Denver & Rio Grande Western Railroad. Several companies have been reported as having plans for the installation of retorting plants, but up to January 1, 1920, only one seems to have made actual progress. This company, the Rocky Mountain Refining Co., is reported to have completed and begun the experimental operation of a 25-ton retort in Kyune Canyon. The DeBrey process is used.

Probably the richest shale in Utah is to be found near Watson, and therefore several companies have begun the erection of plants in that vicinity. The Ute Oil Co. has assembled the material for a large plant on White River about 2 miles above White River station on the stage road between Watson and Vernal. This plant is to consist of a series of retorts of the Wallace type. Each retort consists of a metal cylinder in the middle of which there is a perforated tube for the removal of the oil vapors. Heat is applied externally, and it is claimed for the process that the removal of the vapors is effected in such a way that they are not subjected to temperatures which would produce further cracking and perhaps result in the development of less valuable products. May 1, 1922, found this plant still uncompleted.

The Western Shale Oil Co., on January 1, 1920, completed a single-unit Galloupe retort which had a rated capacity of 16 tons of shale a day, on its property 4 miles east of Uto switch, on the Uintah Railway near Watson. Late in 1920 the condenser house of this plant was destroyed by fire, but the construction of a bench of four retorts

was well along at that time, so that the operation of the plant was interrupted only temporarily.

The retort is made entirely of cast iron. It is about 20 feet high and consists of two principal parts, an outer stationary shell 2 feet in diameter and an inner core made to revolve and carry the shale down through the retort. The outer shell is cast in segments 1 foot high, each having on the inner side a series of staggered shelves projecting about 4 inches into the center. The inner core consists of a segmented hollow cylinder with staggered fins projecting about 4 inches on the outside. These fins are so placed that when the core is suspended inside the outer shell they clear the shelves by about a quarter of an inch. When the retort is in operation the core is suspended on ball bearings and revolved so that the finely crushed shale, which is fed continuously at the top, is scraped from each shelf to the one below by the fins. Each segment of the shell is provided with an exit tube for the vapors, so that they are removed to the condensers as soon as they are formed and not subjected to additional heat and cracked into undesirable compounds. The shale after passing down through the retort is carried through a shale seal and drops into the firebox below, where it is completely burned before it is removed to the spent-shale dump. Heat from the spent-shale fire below the retort passes up inside the core as well as outside the outer shell and is conducted through the fins and shelves to the shale. Air-cooled condensers are used to convert the vapors into liquid products.

The Western Shale Oil Co.'s equipment includes bunk houses, office, laboratory, and a well-appointed mess house.

WYOMING.

OIL SHALES OF THE GREEN RIVER FORMATION.

GEOGRAPHY.

That portion of southwestern Wyoming which is shown on the accompanying map (Pl. XVIII) and in which the most valuable shale beds occur includes the southern part of the Green River Basin and the western rim of the Southern Red Desert Basin. The surface is in most places rolling and covered with vegetation such as is characteristic of arid regions. Trees grow only along the streams and in a few small upland areas. The region is drained through Green River and its tributaries except in the area adjacent to the west line of the State, where the run-off finds its way to Great Salt Lake by the way of Bear River. Steep cliffs mark the eastern margin of

the main basin, and the Green River valley is bordered by precipitous walls for several miles near the town of Green River. Altitudes range from 5,900 feet above sea level on Green River near Linwood to 8,750 feet in the southwestern part of the area shown on the map.

Green River has its beginning far to the north, in the Wind River Mountains, but its principal tributaries in this area, Blacks Fork and Henrys Fork, rise in the Uinta Mountains south of this area, in northern Utah. Aside from the three streams mentioned above, together with Hams Fork, a tributary of Blacks Fork, and Bear River, there are in this area very few streams that carry water the year round.

The main line of the Union Pacific Railroad crosses the area in a general westerly direction and is joined at Granger by the Oregon Short Line, which connects with points to the northwest. Rock Springs, Kemmerer, and Evanston, coal-mining towns, and Green River, a railroad division point, are the principal towns of the region. Several villages have been established in the irrigated district around old Fort Bridger and along Henrys Fork near the south line of the State. Many of the towns on the railroad consist of only a few houses, a store, and a post office. The Lincoln Highway follows in general the line of the Union Pacific Railroad, and good automobile roads connect many of the smaller towns with the railroad and this highway.

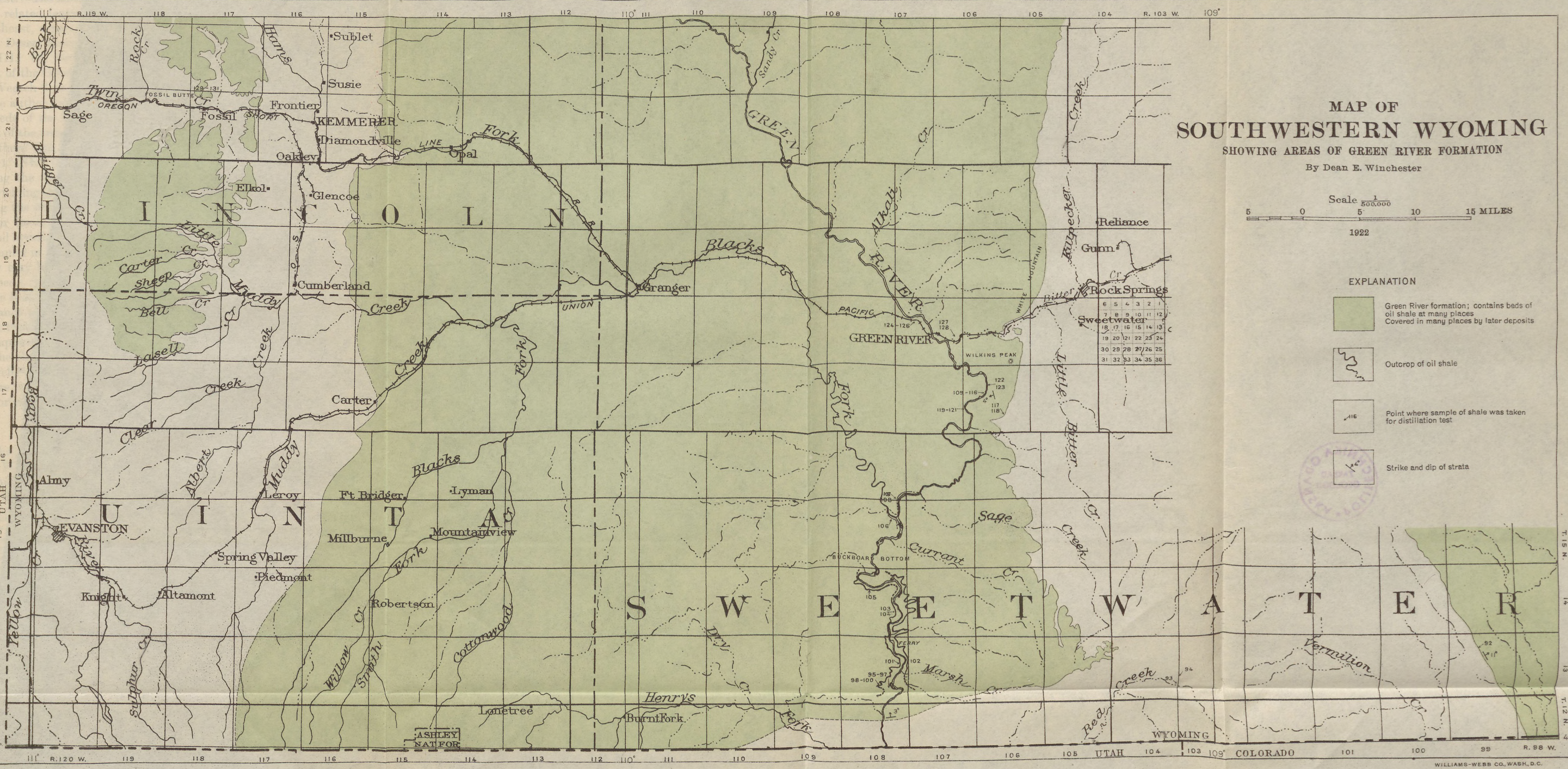
That part of the Green River Basin north of the Union Pacific Railroad has not been studied in detail, but the approximate area covered by the Green River formation is shown on the general map (Pl. I).

The Southern Red Desert Basin in Wyoming and its possible extension in Colorado have also not been studied in detail. Shale collected by the writer on the western margin of this area suggests that perhaps there are beds of commercially valuable oil shale there.

Although the data available indicate that the oil shale in southwestern Wyoming is in thin beds and that rich shale underlies a comparatively small area, the knowledge of the part of the region north of the Union Pacific Railroad and of the Southern Red Desert Basin is so meager that any estimate of the amount of shale in Wyoming is very hazardous. However, it is thought that the total quantity is not less than 7,176,000,000 short tons of shale that will yield at least 15 gallons to the ton. Perhaps not more than 60 per cent of this total would be recovered, even under the most ideal mining conditions.

GEOLOGY.

Oil-yielding shale is present in three distinct areas. The central area, to which the name Green River Basin is applied, is by far the


MAP OF
SOUTHWESTERN WYOMING
SHOWING AREAS OF GREEN RIVER FORMATION
By Dean E. Winchester
Scale 1/500,000
5 0 5 10 15 MILES
1922
EXPLANATION
Green River formation; contains beds of oil shale at many places
Covered in many places by later deposits
Outcrop of oil shale
Point where sample of shale was taken for distillation test
Strike and dip of strata
LINCOLN
UINTA
SWEETWATER
UTAH
WYOMING
COLORADO
Sublet
Susie
Sage
Fossil
Frontier
KEMMERER
Diamondville
Oakley
Opal
Elkol
Glencoe
Cumberland
Granger
Carter
Almy
EVANSTON
Leroy
Ft Bridger
Lyman
Millburne
Mountainview
Spring Valley
Piedmont
Knight
Altamont
Robertson
Lonetree
Burntfork
ASHLEY NAT FOR
Reliance
Gunn
Rock Springs
Sweetwater
GREEN RIVER
WILKINS PEAK
BUCKBOARD BOTTOM
FERRY
GREEN RIVER
Blacks Fork
Hams Fork
Henrys Fork
Muddy Cr
Bitter Cr
Little Bitter Cr
Killpecker Creek
Vermilion Cr
Red Creek
Sage Creek
Currant Cr
Marsh Cr
Smiths Fork
Cottonwood
Willow Cr
Sulphur Cr
Yellow Cr
Bear River
Clear Creek
Albert Cr
Lasell
Bell Cr
Carter Cr
Sheep Cr
Little Muddy Cr
Twin Cr
Bridger Cr
Sandy Cr
Alkali Cr
Dry Cr
OREGON SHORT LINE R.R.
UNION PACIFIC
FOSSIL BUTTE
R.115 W.
R.120 W.
R.103 W.
R.98 W.
T.22 N.
T.12 N.
T.15 N.
WILLIAMS-WEBB CO., WASH., D.C.

largest. The Rock Springs uplift, on the east, described by Schultz,[17] and related features near the Colorado-Wyoming State line, to the southeast, separate the main area from the much smaller Southern Red Desert Basin, only the western rim of which is shown on Plate XVIII. On the west the Green River Basin is separated from the area of the Green River formation in the vicinity of Fossil, described by Veatch [18] as the Fossil syncline, by an anticlinal fold which the same author called the Meridian anticline.

Beds of the Green River formation are only slightly tilted in any part of the area shown on Plate XVIII. Along the western rim of the Southern Red Desert Basin the oil shale at its outcrop dips as much as 11° NE., but it flattens rapidly toward the center of the basin. Along the east and west sides of the main Green River Basin the oil-yielding shale shows dips not exceeding 3° or 4°, but in some places along the north flanks of the Uinta Mountains the beds of the Green River formation are tilted at greater angles. The oil shale of the Fossil syncline is practically horizontal at every point examined.

Faults in the Green River shale were noted in only one area, but they may be present at many other places within the area here described. West of Green River, near the center of T. 15 N., R. 108 W., there is an area perhaps half a mile wide and extending an unknown distance to the west, where the rocks are crumpled and cut by east-west trending faults. On both sides of this disturbed zone the strata are apparently unaffected.

The channel sandstone of Lee,[19] which is the Tower sandstone of Powell,[20] forms vertical cliffs in the vicinity of Green River, Wyo., where it rests on an irregular surface of shale and is itself very much distorted, whereas the shale beneath is not deformed.

STRATIGRAPHIC SECTIONS.

The following stratigraphic sections were measured in southwestern Wyoming and show the general character of the Green River formation in the southern parts of the Green River and Southern Red Desert basins:

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[17] Schultz, A. R., The southern part of the Rock Springs coal field, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 381, pp. 218–220, 1910.

[18] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: U. S. Geol. Survey Prof. Paper 56, pp. 108–110, 1907.

[19] Lee, W. T., and others, Guidebook of the western United States, Part B, The Overland Route: U. S. Geol. Survey Bull. 612, p. 74, 1915.

[20] Powell, J. W., Geology of the eastern portion of the Uinta Mountains, pp. 40, 45, U. S. Geol. and Geog. Survey Terr., 2d div., 1876.

Sections of parts of Green River formation in southwestern Wyoming.

T. 14 N., R. 99 W.

	Ft.	in.
Sandstone, coarse grained, not massive	50	
Sandstone, containing fossil shells		4
Sandstone, coarse grained, thin bedded	10	
Covered, probably sandy shale	35	
Sandstone, coarse	8	
Covered, mostly shale	30	
Shale, papery, drab, lean	5	
Shale, thin, barren, and sandstone	72	
Shale, drab, thin, lean	3	
Shale, thin, drab, barren	20	
Shale, thin, lean	30	
Sandstone, concretionary	1	
Shale, thin, lean	14	
Oolite and chert		
Shale, thin bedded, lean	14	6
Shale, thin bedded; weathers blue; rich	2	
Shale, gray, sandy (not included in sample)	1	7
Sandstone, yellow (not included in sample)		1
Shale, thin bedded; weathers blue; rich	3	
(sample 92; 30 gallons).		
Shale, yellow, sandy	28	
Shale, papery, lean	40	
Shale, drab, fissile	10	
Sandstone, concretionary	1	
Shale, drab, papery	13	
Oolite		6
Shale, drab, papery	10	
Sandstone, oolitic		4
Shale, drab, fissile	12	6
Sandstone, micaceous	1	
Sandstone, yellowish	3	
Shale, drab, thin sandstone lenses	26	
Sandstone, shaly, yellowish	1	
Shale, drab, papery, barren	5	
Sandstone, shaly, yellowish	1	6
Shale, greenish drab	37	
Maroon clay shale (probably Wasatch).		
Total section	489	10
Total shale yielding 15 gallons to the ton	6	8
Total shale yielding 30 gallons to the ton	6	8

T. 13 N., R. 108 W.

	Ft.	in.
Sandstone, ferruginous, containing fossil shells		6
Shale and sandstone	500±	
Shale, thin, brown	5±	
Shale, thin, brown (sample 100; 3 gallons)	5	
Shale, thin, brown	2	6
Shale, hard, black, rich		½
Shale, brown, soft		5
Shale, hard, black, rich		1
Shale, brown, soft		8
Shale, hard, black, rich		2
Shale, brown, soft	1	8
Shale, hard, black, rich		3
(sample 99; 19 gallons).		
Shale, light brown, lean (sample 98; 3 gallons)	5	
Interval	25	
Shale, lean (?)	10±	

T. 13 N., R. 108 W.—Continued.

	Ft.	in.
Shale, dark brown (sample 95; 13 gallons)	5	
Shale, thin bedded, tough	10	6
Shale, thin bedded, tough (sample 96; 4 gallons)	5	4
Shale, thin bedded, tough	2	6
Shale, massive, light brown	2	6
Shale, massive, light brown (sample 97; 6 gallons)	4	10
Shale, lean.		
Total section	586±	
Total shale yielding 15 gallons to the ton	5	9½

Sec. 27, T. 17 N., R. 106 W.

	Ft.	in.
Shale, drab	45	
Sandstone, platy	16	
Shale, lean	22	
Sandstone, brown, platy	7	
Shale, hard, not so rich	24	
Shale, hard, thin, platy [21] (sample 118; 14 gallons)	5	6
Shale, hard, dark [21]	2	3
Shale, hard, dark, rich [21] (sample 117; 19 gallons)	8	1
Shale, weathers to thin plates; part of member will yield small amount of oil	120	
Covered, mostly light-colored shale or clay	75	
Clay, mostly gray, with some red	80	
Clay, gray, yellow, green, and red, with beds of yellow sandstone. All beds very lenticular. A 40-foot bed of massive sandstone at one place splits and within 100 yards along its outcrop is represented by variegated clay beds, with a few thin sandstones	75	
Total section	479	10
Total shale yielding 15 gallons to the ton	8	1

Secs. 17 and 19, T. 17 N., R. 106 W.

	Ft.	in.
Sandstone, massive, brown, coarse (Tower sandstone of Powell)	125	
Sandstone, thin bedded	35	
Shale, papery, gray	25	
Sandstone, shaly, gray	32	
Shale, sandy, lean	65	
Shale, hard; contains fish remains (sample 120; 14 gallons)	5	
Shale, lean	20	
Shale, thin, with lenses of very rich waxy shale	55	
Shale, hard	15	
Shale, hard (sample 119; 12 gallons)	5	
Shale, hard, lean	12	
Shale, gray, sandy	20	
Shale, hard, rich	1	4
Shale, gray, sandy, thin sandstones, and a few 1 to 3 inch beds of rich shale	90	
Shale, hard, thin, medium rich	1	6
Shale, barren	15	
Shale, medium, with large gypsum crystals	1	6

[21] Probably same zone as lower 22 feet 8 inches of section measured in secs. 17 and 19 of this township.

Secs. 17 and 19, T. 17 N., R. 106 W.—Continued.

	Ft.	in.
Shale, thin, barren	80	
Shale, medium, with gypsum crystals		8
Shale, gray, sandy	26	
Shale, medium, with gypsum crystals	1	6
Shale, hard, rich		10
Sandstone, thin, gray	8	
Shale, hard, rich		10
Shale, gray, sandy	17	
Shale, hard, rich		2
Shale, thin, gray, sandy	9	2
Shale, hard, rich		10
Shale, sandy	118	
Sandstone, gray	4	
Shale, sandy, greenish	6	
Sandstone, gray, thin bedded	1	
Shale, sandy, green	27	
Shale, sandy, thin bedded, gray	21	
Sandstone and shale, green, in beds 2 feet thick; sandstone, concretionary	58	
Shale, sandy, gray, slope	97	
Sandstone, massive, cross bedded, forming ledge and capping hill	5	
Shale, forming slope	43	
Sandstone, rather massive, forming ledge	10	
Shale, soft, thin, platy, barren	30	
Shale, medium hard, rather thin, very lean	4	11
Shale, medium hard (sample 116; 4 gallons)	4	10
Shale, sandy, lean to barren	70	
Shale, medium hard, very lean	10	
Shale, lean	4	6
Sandstone, brown, persistent		8
Shale, lean	3	6
Shale, hard to medium hard (sample 115; 9 gallons)	4	6
Shale, lean to barren	75±	
Shaly sandstone, barren	15	
Shale, sandy, forming slope, lean	47	
Shale, hard (sample 114, lower 4½ feet; 11 gallons)	5	6
Shale, hard (sample 113; 10 gallons)	5	3
Shale, hard	1	4
Sandstone		3
Shale, fairly soft, thin bedded (sample 112; 9 gallons)	2	9
Shale, hard	1	
Shale, hard, rich (sample 111; 19 gallons)	5	4
Shale, hard, rich (sample 110; 19 gallons)	6	3
Shale, soft		7
Shale, hard, rich (sample 109; 11 gallons)	2	5
Shale, soft		6
Shale, hard, rich	2	3
Total section	1,360±	
Total shale yielding 15 gallons to the ton	11	7

Along Bitter Creek, T. 18 N., R. 107 W.

	Ft.	in.
Sandstone, massive, brown	135	
Shale, lean to barren	3	
Shale, hard	6	
Sandstone, brown, massive	1	
Shale, lean to rich	1	
Sandstone, brown, massive	5	
Shale, lean, papery	11	

Along Bitter Creek, T. 18 N., R. 107 W.—Contd.

	Ft.	in.
Sandstone		2
Shale, hard, rich		6
Sandstone		3
Shale, hard, dark		8
Shale, brown, tough (sample 128; 7 gallons)		4
Shale, hard, rich, dark	1	4
Sandstone		3
Shale, hard, rich	2	6
Shale, hard, rich (sample 127; 18 gallons)	6	3
Sandstone		6
Shale, hard, rich	6	2
Sandstone, hard, massive		6
Shale, hard, gray, sandy, lean to barren	13	
Shale, soft, greenish, lean	15	
Partly masked, barren gray shale and sandstone, with some lean papery shale	55	
Sandstone, platy	2	
Shale, lean, soft	2	6
Shale, greenish gray	21	6
Sandstone, thin bedded	11	
Covered, mostly barren gray sandy shale with a few ledges of gray shaly sandstone	128	
Sandstone, platy	3	
Shale, greenish	7	
Covered, mostly barren gray sandy shale, with a few ledges of gray shaly sandstone	110	
Shale; weathers papery	1	6
Sandstone		6
Shale; weathers papery	2	
Shale, gray, sandy, with layers of shaly sandstone	21	
Shale, greenish	20	
Shale, gray, sandy, with layers of shaly sandstone	17	
Shale, greenish, with brown sandstone lentils	20	
Sandstone, brown, with some clay shale	35	
Sandstone, thin, platy	4	
Sandy shale and shaly sandstone, gray, barren	85	
Total section	755	5
Total shale yielding 15 gallons to the ton	15	5

White Mountain, sec. 36, T. 19 N., R. 106 W.

	Ft.	in.
Sandstone, brown, coarse (Tower sandstone of Powell)	245	
Shale, gray, sandy, and shaly sandstone, with three beds of rich shale each 3 inches thick in lower part	265	
Shale (estimated yield, 12 to 15 gallons)	3	
Shale, gray, sandy, and thin sandstone with two or three 1-inch beds of rich shale	37	
Sandstone, gray, ripple marked	1	
Shale, sandy, gray, and shaly sandstone	22	
Sandstone, shaly, yellow	2	
Shale, sandy, and clay, with a few thin sandstone beds; color predominantly white	133	
Sandstone, green, shaly	33	
Shale, gray, sandy, and thin sandstone	58	
Shale, green, sandy, and green sandstone	17	
Shale, greenish drab, sandy	35	
Sandstone, chalky, cross-bedded, brown	2	

White Mountain, sec. 36, T. 19 N., R. 106 W.—Continued.

	Ft.	in.
Shale, drab, sandy	95	
Sandstone, ferruginous		4
Shale, sandy, gray-green, and shaly sandstone	75	
Sandstone, shaly	2	
Shale, papery, lean, with 2-inch beds of rich shale and some thin beds of sandstone	87	
Sandstone, with clay balls		6
Shale, papery, lean	26	
Shale, sandy, gray	24	
Sandstone, shaly, gray, fossiliferous	2	
Shale, carbonaceous	8	
Clay, sandy, gray	40	
Sandstone, coarse, gray, possibly base of Green River formation	1	
Clay, somewhat sandy, gray	55	
Shale, clay, variegated, red at top	33	
Sandstone, yellowish green, friable	30	
Total section	1,331	10

Fossil Butte.

	Ft.	in.
Sandstone, shaly	95	
Sandstone, coarse, brown		3
Shale, hard, rich, dark; weathers blue (sample 131; 50 gallons)	2	
Sandstone, shaly	7	
Shale, hard, rich; weathers blue	1	
Alternating bands of coarse sandstone and shale	8	

Fossil Butte—Continued.

		Ft.	in.
Sandstone, cherty			10
Shale, lean, chalky, thin bedded		15	
Sandstone, reddish brown			8
Shale, lean, chalky, thin bedded		2	6
Sandstone, massive		8	6
Chalk			3
Sandstone, massive, yellow		3	2
Shale	(sample 130; 10 gallons).		10
Sandstone, gray (discarded)			5
Shale, hard, light brown		1	7
Sandstone, light brown (discarded)			1
Shale, hard, brown, rich; weathers blue		1	1
Sandstone, yellow			¼
Shale, hard, brown, rich; weathers blue			10
Shale, white, chalky	(sample 129; 8 gallons).		11
Shale, hard, brown			6
Shale, white, chalky; contains abundant fish remains		1	2
Shale, lean, thin bedded		18	
Sandstone, drab		10	
Shale, sandy		5	
Sandstone, coarse		65	
Total section		250	1¼
Total shale yielding 15 gallons to the ton		3	
Total shale yielding 30 gallons to the ton		3	

Samples **467–472.** About 2 miles southwest of Fossil, Wyo., on Oregon Short Line Railroad, in T. 21 N., R. 117 W. Green River formation.

Section near Fossil, Wyo.

	Thickness.	Sample No.	Oil (gallons per ton).	Nitrogen.	
				Per cent in shale.	Theoretical equivalent in ammonium sulphate (pounds per ton).
	Ft. in.				
Shale forming hilltop.					
Shale; weathers purplish gray; curly laminae	2				
Shale, brown, calcareous[a]	7	467	37	0.35	33.0
Shale, brown, weathering purplish	10				
Shale, sandy to calcareous	7 6				
Shale, brown, slightly calcareous and sandy near base	7 1	468	6	.03	2.8
Sandstone, orange-colored	2				
Shale, fissile, dark gray	5	469	4	None.	
Shale, brown, weathering purplish gray	3	470	7	.09	8.4
Shale, fissile, papery layers where weathered	5	471			
Sandy limonite	6				
Shale, sandy and calcareous	2 4				
Clay	2				
Shale, tough, gray, with fine brown laminae	3 10				
Limestone, argillaceous, gray	4 2				
Shale, brown and gray laminae, with thin limestone layers	3 6				
Shale, brown, with gray laminae	3 4				
Clay[a]	7				
Shale, brown, laminated, calcareous, rich in fossil fish	1	472	15	.14	12.9
Shale, tough, brown, laminated	4 2				
Lower strata not exposed.					

[a] Not included in sample.

BLACK SHALES OF THE PHOSPHORIA FORMATION.

The rocks of the Phosphoria formation crop out in the Teton and Big Hole mountains along and near the Idaho-Wyoming State line and thence southward are to be seen in most of the mountains all the way to Ogden, Utah They are present along the Salt River Range in Wyoming and also encircle the Uinta Mountains of northeastern Utah. Throughout the region brown or black shale is associated with the phosphate rock in beds whose thickness ranges from 50 to more than 200 feet. Wherever these black shales crop out they were prospected by the early settlers for coal. More recently new openings have been made at a few points for the mining of phosphate rock. Unweathered samples of the shales were obtained in the mines and prospects at numerous places that can be regarded as representative of the area. The negative results from the distillation of the samples collected from these areas therefore prove that the black shale of the Phosphoria formation in southeastern Idaho and adjacent parts of Wyoming and Utah is not oil shale, there being but few samples that yield as much as 1 gallon of oil to the ton.

Sections and yield of samples from Phosphoria formation along and near Idaho-Wyoming State line south of Yellowstone Park.

No. on map.	Locality.	Section.	Thickness.	Sample No.	Oil (gallons per ton).
			Ft. in.		
14	North of Victor-Jackson road, 2 miles east of State line in Wyoming, T. 41 N., R. 119 W.; prospect tunnel.	Shale, cherty	5+		
		Shale, brown, phosphatic	5 6	422	None.
		Shale and chert	1 1		
		Phosphatic rock, soft, oolitic	2	423	None.
		Shale and chert	3 7		
		Shale, black, phosphatic	2 10	424	None.
		Phosphate rock, hard, black	1		
		Chert	3+		
15	Black shale outcrop along road on west side of Teton Pass, Wyo., in T. 41 N., R. 19 W.	Shale, black	5	425	None.
17	Count's ranch, upper end of Snake River canyon, below mouth of Hoback River, T. 39 N., R. 116 W., Wyo.	Chert	20+		
		Shale, phosphate, and sandy beds, all black; shaly layers included in sample.	27 3	430	Trace.
		Shale and phosphate interbedded with limestone; shaly layers sampled.	21 1	431	Trace.

Samples **450–454**. Near McDougall Pass, Salt River Range, Wyo., T. 33 N., R. 117 W., unsurveyed sec. 16. Phosphatic black shales of Phosphoria lying between two principal phosphatic beds. Thickness of beds sampled about 17 feet. Result of distillation: Oil, none. The chemical composition of the phosphate beds is shown in the table on page 129.

Sample **455**. McDougall Pass, Salt River Range, Wyo., T. 33 N., R. 117 W., unsurveyed sec. 9. Black shale 10 feet thick at top of Phosphoria formation. Result of distillation: Oil, none.

Sample **456**. Raymond Canyon, Wyo., NE. ¼ sec. 6, T. 26 N., R. 120 W. Black phosphatic shales from prospect tunnel in Phosphoria formation. Result of distillation: Oil, none

Samples **457–458**. Phosphate mine in T. 24 N., R. 119 W., 1 mile northeast of Cokeville, Wyo. Black shale associated with phosphate bed of Phosphoria formation. Thickness of beds sampled about 4 feet. Result of distillation: Oil, none.

MISCELLANEOUS SAMPLES.

Samples **464–465**. Half a mile east of phosphate mine near Cokeville, Wyo., in T. 24 N., R. 119 W. Impure coal and bony shale in Bear River formation. Sample 464 from bed 3 feet thick; sample 465 from prospect dump. Results of test: Sample 464, oil, 1 gallon to the ton; sample 465, oil, 1 gallon to the ton.

Sample **466**. Impure bony coal in Bear River formation at abandoned slope mine near Sage station, Wyo., in T. 21 N., R. 119 W. Sample taken from dump. Result of test: Oil, 11 gallons to the ton; nitrogen, 0.65 per cent, equal to 61.2 pounds of ammonium sulphate to the ton.

Sample **473**. Abandoned coal mine at Almy, about 4 miles northwest of Evanston, Wyo., in T. 16 N., R. 120 W. Sample includes 5 feet of impure coal and black shale above main coal bed. Cretaceous age. Results of test: Oil, 5 gallons to the ton, nitrogen, 0.51 per cent, equal to 47.8 pounds of ammonium sulphate to the ton.

Sample **219**. Shale, collected along road from Raymond to Snells, on Crooked Creek, in sec. 33, T. 58 N., R. 95 W., Big Horn County, by C. J. Hares, near base of Thermopolis shale (Upper Cretaceous). Results of distillation: Oil, none; ammonium sulphate, 4.16 pounds to the ton.

Sample **220**. Shale, collected north of Beer Mug Ridge, near Hanna, by C. F. Bowen, October 1, 1915, from Mowry shale (Upper Cretaceous). Results of distillation: Oil, 1 gallon to the ton; ammonium sulphate, 1.4 pounds to the ton.

RESULTS OF DISTILLATION TESTS.

Of the 68 samples of shale and carbonaceous materials from Wyoming 45 represent material from the Green River formation, showing a maximum yield of oil of 50 gallons to the ton; 15 samples represent black shales of the Phosphoria formation, none of which showed more than a trace of oil when distilled. None of the samples of miscellaneous materials proved particularly interesting.

Results of distillation of shale and coal samples from Wyoming.

Sample No.	Location. Sec.	T.	R.	Material.	Thickness of shale sampled.	Gravity of oil at 60° F. Specific gravity.	Baumé.	Yield of oil per short ton of shale.	Yield of ammonium sulphate per short ton of shale.	Nitrogen in shale.	Theoretical equivalent of nitrogen in ammonium sulphate per ton of shale.
					Ft. in.		°	*Gallons.*	*Pounds.*	*Per cent*	*Pounds.*
5[a]	Green	River.	.....	Shale, Green River formation.	.....	0.9130	23.3	29	9.0	.....	.....
92	9	13 N.	99 W.	.....do.....	5	.8709	30.79	30	3.94	.....	.....
93[b]	19	13 N.	103 W.	.....do.....	4	.8760	29.81	11	4.88	.....	.....
94[b]	25	13 N.	104 W.	.....do.....	2	.8937	26.65	15	5.91	.....	.....
95	26	13 N.	108 W.	.....do.....	5	.9496	17.43	13	7.49	.....	.....
96	26	13 N.	108 W.	.....do.....	5 4	.9277	20.91	4	12.69	.....	.....
97	26	13 N.	108 W.	.....do.....	4 10	.9062	24.49	6	4.71	.....	.....
98	27	13 N.	108 W.	.....do.....	5	.....	.....	3	7.18	.....	.....
99	27	13 N.	108 W.	.....do.....	3 3½	.....	.....	19	9.32	.....	.....
100	27	13 N.	108 W.	.....do.....	5	.....	.....	3	9.52	.....	.....
101	13	13 N.	108 W.	.....do.....	2 7	.8994	25.65	34	5.70	.....	.....
102	13	13 N.	108 W.	.....do.....	4	.9060	24.52	15	8.50	.....	.....
103	23	14 N.	108 W.	.....do.....	2 11	.8818	28.77	32	6.62	.....	.....
104	23	14 N.	108 W.	.....do.....	11	.8892	27.44	20	4.39	.....	.....
105	9	14 N.	108 W.	.....do.....	4 2	.8885	27.56	7	2.47	.....	.....
106	11	14 N.	108 W.	.....do.....	7 2	.9183	22.45	9	11.14	.....	.....

[a] Hand specimen collected by W. T. Lee.

[b] Collected by A. R. Schultz from fissile shale described as Wasatch in U. S. Geol. Survey Bull. 381, p. 222, 1910, and as Tipton shale member of Green River formation in Bull. 702, pp. 30–31, 1920.

Results of distillation of shale and coal samples from Wyoming—Continued.

Sample No.	Location.				Thickness of shale sampled.	Gravity of oil at 60° F.		Yield of oil per short ton of shale.	Yield of ammonium sulphate per short ton of shale.	Nitrogen in shale.	Theoretical equivalent of nitrogen in ammonium sulphate per ton of shale
	Sec.	T.	R.	Material.		Specific gravity.	Baumé.				
					Ft. in.		°	*Gallons.*	*Pounds.*	*Per cent*	*Pounds*
107	36	16 N.	108 W.	Shale, Green River formation.	5 3	0.9022	25.18	21	5.69	.....	.....
108	36	16 N.	108 W.	.....do.....	6	.8925	26.86	13	5.06	.....	.....
109	17	17 N.	106 W.	.....do.....	5 9	.8798	29.12	11	5.51	.....	.....
110	17	17 N.	106 W.	.....do.....	6 3	.9190	22.34	19	9.82	.....	.....
111	17	17 N.	106 W.	.....do.....	5 4	.9111	23.66	19	8.81	.....	.....
112	17	17 N.	106 W.	.....do.....	5 1	.9075	24.26	9	7.59	.....	.....
113	17	17 N.	106 W.	.....do.....	5 3	.9050	24.69	10	5.10	.....	.....
114	17	17 N.	106 W.	.....do.....	4 6	.9143	23.12	11	3.86	.....	.....
115	17	17 N.	106 W.	.....do.....	4 6	.8848	28.22	9	2.28	.....	.....
116	17	17 N.	106 W.	.....do.....	4 10	.....	.....	4	3.02	.....	.....
117	27	16 N.	106 W.	.....do.....	8 1	.9003	25.50	19	8.68	.....	.....
118	27	16 N.	106 W.	.....do.....	5 6	.9120	23.50	14	5.50	.....	.....
119	19	17 N.	106 W.	.....do.....	5	.8963	26.19	12	7.17	.....	.....
120	19	17 N.	106 W.	.....do.....	5	.8702	30.88	14	7.93	.....	.....
121	16	17 N.	106 W.	.....do.....	4	.9456	18.05	14	11.19	.....	.....
122	9	17 N.	106 W.	.....do.....	7 3	.9077	24.23	14	4.27	.....	.....
123	9	17 N.	106 W.	.....do.....	6 6	.9197	22.22	19	2.74	.....	.....
124	8	18 N.	107 W.	.....do.....	5 9	.9027	25.09	13	5.80	.....	.....
125	8	18 N.	107 W.	.....do.....	3 3½	.8800	29.09	6	3.73	.....	.....
126	8	18 N.	107 W.	.....do.....	1 8	.9182	22.47	29	11.71	.....	.....
127	24	18 N.	107 W.	.....do.....	6 3	.9148	23.03	18	7.27	.....	.....
128	24	18 N.	107 W.	.....do.....	2 4	.8862	27.97	7	5.65	.....	.....
129	5	21 N.	107 W.	.....do.....	1 7	.8705	30.82	8	.69	.....	.....
130	5	21 N.	107 W.	.....do.....	5	.8837	28.42	10	.86	.....	.....
131	5	21 N.	107 W.	.....do.....	2	.8889	27.49	50	1.99	.....	.....
219	33	58 N.	95 W.	Shale, Thermopolis shale.	.....	.....	.....	.....	4.16	.....	.....
220	.....	.....	.....	Shale, Mowry shale.	.....	.....	.....	1	1.4	.....	.....
422	.....	41 N.	119 W.	Shale, Phosphoria formation.	5 6	.....	.....	None.	.....	.....	.....
423	.....	41 N.	119 W.	.....do.....	3 7	.....	.....	.....	.....	.....	.....
424	.....	41 N.	119 W.	.....do.....	2 10	.....	.....	None.	.....	.....	.....
425	.....	41 N.	119 W.	.....do.....	5	.....	.....	None.	.....	.....	.....
430	.....	39 N.	116 W.	.....do.....	27 3	.....	.....	Trace.	.....	.....	.....
431	.....	39 N.	116 W.	.....do.....	21 1	.....	.....	Trace.	.....	.....	.....
450	16	33 N.	117 W.	.....do.....	4 8	.....	.....	None.	.....	.....	.....
451	16	33 N.	117 W.	.....do.....	4 2	.....	.....	None.	.....	.....	.....
452	16	33 N.	117 W.	.....do.....	2 4	.....	.....	None.	.....	.....	.....
453	16	33 N.	117 W.	.....do.....	1 3	.....	.....	None.	.....	.....	.....
454	16	33 N.	117 W.	Phosphate rock, Phosphoria formation.	3 3	.....	.....	None.	.....	.....	.....
455	9	33 N.	117 W.	Shale, Phosphoria formation.	10	.....	.....	None.	.....	.....	.....
456	6	26 N.	120 W.	.....do.....	.....	.....	.....	None.	.....	.....	.....
457	.....	24 N.	119 W.	.....do.....	4	.....	.....	None.	.....	.....	.....
458	.....	24 N.	119 W.	.....do.....	4	.....	.....	None.	.....	.....	.....
464	.....	24 N.	119 W.	Coal and shale, Bear River formation.	3	.....	.....	1	.....	.....	.....
465	.....	24 N.	119 W.	.....do.....	.....	.....	.....	1	.....	.....	.....
466	.....	21 N.	119 W.	Shale, Bear River formation.	.....	.....	.....	11	.....	0.65	61.2
467	.....	21 N.	117 W.	Shale, Green River formation.	2 10	.....	.....	37	.....	.35	33.0
468	.....	21 N.	117 W.	.....do.....	7 1	.....	.....	6	.....	.03	2.8
469	.....	21 N.	117 W.	.....do.....	5	.....	.....	4	.....	.....	.....
470	.....	21 N.	117 W.	.....do.....	3	.....	.....	.....	.....	.09	8.4
471	.....	21 N.	117 W.	.....do.....	5	.....	.....	.....	.....	.....	.....
472	.....	21 N.	117 W.	.....do.....	8 6	.....	.....	15	.....	.14	12.9
473	.....	21 N.	117 W.	Coal and shale, Cretaceous.	5	.....	.....	5	.....	.51	47.8

DEVELOPMENTS.

Several companies hold shale-land claims in the vicinity of Green River and Fossil, Wyo. No one, however, so far as the writer is aware, has installed a retort for the manufacture of shale oil.

SHALE OIL.

CHARACTER.

On the assumption that the oil obtained from oil shale is manufactured from materials the greater part, at least, of which are not and never have been petroleum, it is evident that the character of the shale oil must depend primarily upon two factors—first, the raw materials, and second, the conditions existing in the retorts when the shale oil is made. In the Rocky Mountain region there are several different kinds of material from which it is possible to make oil—massive bedded brown shale, paper shale, thinly laminated velvet shale, massive jet-black shale with conchoidal fracture, cannel coal, etc.—but in the opinion of the writer these physical differences in the shale are due largely to accidents of deposition, and the material from which the oil is made is essentially the same in most of the shales and therefore will have much less influence upon the products of distillation than the conditions of pressure, temperature, etc., in the retort where the oil is manufactured. However, it is known that the yellowish-brown massive shale from Elko, Nev., will produce oil that is radically different from that obtained from the ordinary rich dark shale of the Uinta Basin when subjected to the same conditions of distillation, and also that in the distillation of the older shales of the Phosphoria formation oil is not produced until much higher temperatures are reached than are required to begin the distillation of oil from the Green River shales, indicating that in these older shales the lighter products of distillation have already been formed and set free by nature. Oil from the older shales has a much higher specific gravity than any of the oils from the Eocene shales. Doubtless, when subjected to the same treatment, the various types of rich shale that are present in any one locality will yield oil of somewhat different properties. However, it is very easy to change the physical and chemical character of the product from any one shale sample by changing the rate of heating, and it is probable that a slight change in pressure in the retort would have as decided an effect upon the character of the oil produced.

It has been proved by a number of independent investigators[21a] that in the distillation of oil shale the primary product is a "solid or semisolid bitumen" which is formed within a comparatively narrow

[21a] McKee, R. H., and Lyder, E. E., Thermal decomposition of oil shales: Columbia Univ. Eng. and Sci. Papers, Aug. 1, 1921, pp. 1–32. Gavin, M. J., personal communication.

range in temperature (about 400° C.) and that the petroleum products obtained in the ordinary distillation of oil shale are the result of the cracking of this primary substance.

Inasmuch as there is as yet (July, 1922) no shale retort of commercial size in operation on American oil shales, there is of course no shale oil that may be considered as typical of the shale oil which is to be made in such plants when they are established, and whatever data are available as to the physical and chemical properties of American shale oil are taken from a study of the oil produced in the small experimental retorts and in the testing apparatus used in the field and in the laboratory. These data are of course interesting in giving a suggestion of the character of the shale oil that may be expected, but the figures and generalizations are at their best only very rough approximations. Shale oils obtained under these uncommercial methods are reddish brown, range from semisolid (vaseline-like) to free-flowing liquid oils, and show a range in specific gravity from 0.8449 (35.7° Baumé) (Elko) to 0.975 (13.6° Baumé) (Dillon). Most of the oils from shales of the Green River formation show a gravity of about 27° Baumé. Fractionation of shale oils obtained in the field stills gives the following analyses:

Results of fractionation of shale oil.

[Shales collected by D. E. Winchester and distilled in small field retort.]

Sample No.	4	6	10	18	19	27	32	51	57
Begins to boil at (°C.)	80	52	50	70	72	65	80	70	54
Distillation (cubic centimeters):									
To 100° C.	6	10	2	2.5	2	4	2.5	7	4
100° to 125° C.	2	.5	3.5	1	1	1.5	3.5	1	2
125° to 150° C.	2	1.5	6.5	2.5	8	1.5	4.5	1	3
Total gasoline	10	12	12	6	11	7	10.5	9	9
150° to 175° C.	2	2	8	6	6.5	3	6	2	5
175° to 200° C.	2	4	6	5	5	3	5	4	4.5
200° to 225° C.	5	4	7.5	5	5	4	6	4	5
225° to 250° C.	7.5	6	7	5	5	5	8	6	5
250° to 275° C.	6	6	7.5	7	7	7	8.5	6.5	7
275° to 300° C.	6	10	13	7	7	17	9	13	12
Total kerosene	28.5	32	49	35	35.5	39	42.5	35.5	38.5
Total distillate	38.5	44	61	41	46.5	46	53	44.5	47.5
Total residuum	61.5	56	39	59	53.5	54	47	51.5	52.5
Amount of oil used	100	100	100	100	100	100	100	96	100
Specific gravity at 60° F.:									
Crude	0.8937	0.8850	0.9138	0.9290	0.9327	0.8946	0.8838	0.9126	0.9126
Gasoline	.7947	.7769	.8090	.7974	.8202	.7849	.7568	.7838	.7605
Kerosene	.8602	.8466	.8260	.8742	.8876	.8722	.8524	.8682	.8538
Residuum	.9695	.9643	.9884	.9894	1.0160	.9684	.9368	.9695	.9628
Asphalt, per cent by weight	1.35	.82	2.82	4.10	3.62	2.49	.47	1.40	1.03
Paraffin do	7.70	6.93	2.22	3.72	1.63	4.56	4.70	9.21	4.00
Sulphur do	.54	1.06				.73	1.42	.41	.69
Nitrogen do	1.848	.887	2.198	1.549	1.643	1.267	1.849	1.820	2.135
Unsaturated hydrocarbons:									
Crude, per cent			82	86	81.6		72		
Kerosene do	55	55	64	71	71	61	57	62	58

Results of distillation by standard method of the oils obtained in the field tests.

[Shales collected by E. G. Woodruff and distilled in large field retort.]

Serial No.	Location (Colorado).	Distillation by Engler's method, by volume.							Unsaturated hydrocarbons (per cent).		Paraffin (per cent).	Asphalt (per cent).
		Begins to boil (°C.)	To 150° C.		150°–300° C.		Residuum.		Crude.	150°–300° C.		
			Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.				
A	Kimball Creek	70	5	0.8020	54	0.8874	41.5	0.9649	66.8	64	.....	2.210
		60	6	.8700	48	.8708	44.0	.9250	.....	50	1.50	.....
B	Parachute Creek	75	2	.....	48	.8646	50.5	.9437	91.6	45	.....	1.907
		80	5	.8020	44	.8508	.....	.9100	.....	55	4.60	.....
C	Conn Creek, No. 1	70	4	.7745	42	.8519	53.4	.9085	75.6	44	.....	.745
		80	2	.....	38	.8373	.....	.8928	.....	.....	3.13	.....
D	Conn Creek, No. 2	70	7	.8205	53	.8889	.....	.....	72.4	57	.....	9.654
		70	10	.....	55	.8585	.....	.....	.....	.....	.....	.....
E	4A ranch	70	5	.7995	51	.8804	44.9	.9605	71.2	56	.....	4.610
		70	6	.8355	38	.8783	.....	.....	.....	.....	.....	.....
F	Shale from Whisky Creek	70	5	.8330	45	.8935	.....	.....	76.8	51	.....	.....
		70	6	.8355	44	.8813	.....	.....	.....	.....	6.00	.....

An examination of these results shows that the oil manufactured in the small field retorts, where the temperature was more nearly under control than in the larger retort, heated over a wood fire, gave a slightly larger percentage of gasoline or distillate up to 150° C. In the same samples the kerosene cut ranged from 28.5 to 49 per cent, and the paraffin from 1.63 to 7.7 per cent; the asphalt in every sample was less than the paraffin. The sulphur and the nitrogen in the oil averaged 0.81 and 1.69 per cent, respectively.

These figures indicate that probably commercial shale oil will be of a paraffin base—that is, it will contain more paraffin than asphaltic compounds—and that it will contain both nitrogen and sulphur compounds. If the latter are present in sufficient quantity they may be a great detriment to the oil, and the nitrogen existing in a free state or as certain organic nitrogen compounds will lessen the value of the oil. The fact that the percentage of nitrogen in the shale increases in direct relation to the oil-yielding capacity of the shale indicates that the nitrogen compounds as well as the oil are produced from the organic constituents of the shale. In the commercial treatment of the oil shales it will be possible and perhaps practicable to convert the nitrogen into some compound that will be of value, as is done in Scotland, where the nitrogen is converted into ammonia and recovered from the permanent gas as ammonium sulphate.

Woodruff and Day [22] reported the presence in shale oil of "pyridine compounds easily extracted from the shale oil by dilute acids," and it has been suggested that these compounds may occur in sufficient quantity to be of value as such. Fifteen samples of oil from shale

[22] U. S. Geol. Survey Bull. 581, p. 7, 1915.

distilled in the field apparatus prior to the 1916 field season were therefore submitted to the Bureau of Mines for study. The samples were chosen to represent wide geographic distribution, as well as great range in character of shale. The following table gives data relative to the samples and the results of the chemical determinations, made by D. T. Day, of the Bureau of Mines.

"Pyridine compounds" in dry distilled shale oil.

Sample No.	Locality.				Nitrogen in original shale (per cent).	Yield of oil (gallons per ton of shale).	Specific gravity of oil.[a]	Pyridine compounds in oil (per cent by weight.)[a]	Ammonium sulphate from gas obtained in distillation of shale (pounds per ton).[a]
	Sec.	T.	R.	State.					
63	20	11 S.	25 E.	Utah	0.53	32	0.8998	3.88	7.0
64	20	11 S.	25 E.	do	.35	15	.8870	4.28	4.1
65	20	11 S.	25 E.	do	.73	32	.9090	2.83	5.4
66	20	11 S.	25 E.	do	.80	55	.9052	3.82	(b)
67	20	11 S.	25 E.	do	1.30	90	.8745	5.99	6.9
69	20	11 S.	25 E.	do	.32	19	.9021	2.38	5.0
77	26	10 S.	25 E.	do	.68	37	.8727	6.13	7.8
87	15	10 S.	25 E.	do		54	.8866	3.47	5.5
88	15	10 S.	25 E.	do		25	.8914	4.64	4.1
92	9	13 N.	99 W.	Wyoming	.60	30	.8709	2.35	3.9
101	13	13 N.	108 W.	do	.68	34	.8994	2.26	5.7
120	19	17 N.	106 W.	do		14	.8702	4.35	7.9
129	5	21 N.	107 W.	do	.10	8	.8705	8.91	.7
131	5	21 N.	107 W.	do	.50	50	.8889	2.36	2.0
132[c]				Nevada	.85	50	.8449	1.25	4.5

[a] Determinations by Bureau of Mines, D. T. Day, chemist.
[b] Not determined.
[c] Collected by David White from a point near Elko, Nev.

The percentage of "pyridine compounds" is large for the samples tested. It is suspected that the distillation of shale with the injection of steam into the heated retort will convert a considerable part of the nitrogen (here present in the oil as "pyridine compounds") into ammonia in the gas, which will be reclaimed as ammonium sulphate. Here again is needed research to determine the effect of steam on the nitrogen of the shale and the relative cost and value, as end products, of ammonia sulphate and the "pyridine compounds" produced by the dry distillation of oil shale.

REFINING.

The refining of shale oil promises to be a rather complicated process, as the oil must be distilled many times in order to separate successfully the different ingredients, which have varying degrees of volatility and specific gravity. A small amount of "shale spirit" may be obtained from the permanent gas derived from the orignal distillation, but most of the valuable hydrocarbon products will be produced from the shale oil itself. The diagram reproduced in figure 4, compiled by H. M. Cadell,[23] shows the products of the various stages of distillation

[23] Cadell, H. M., The story of the Forth, 1913.

roughly in proportion to the amount of the product and illustrates briefly the complexity of the refining industry as well as the variety of products derived from the oil shale of Scotland. Although the products of the American oil-shale industry will doubtless be different from those obtained in Scotland, where the profit is derived largely from liquid and solid products, and also different from those of New South Wales, where the "shale" is used largely in the manufacture

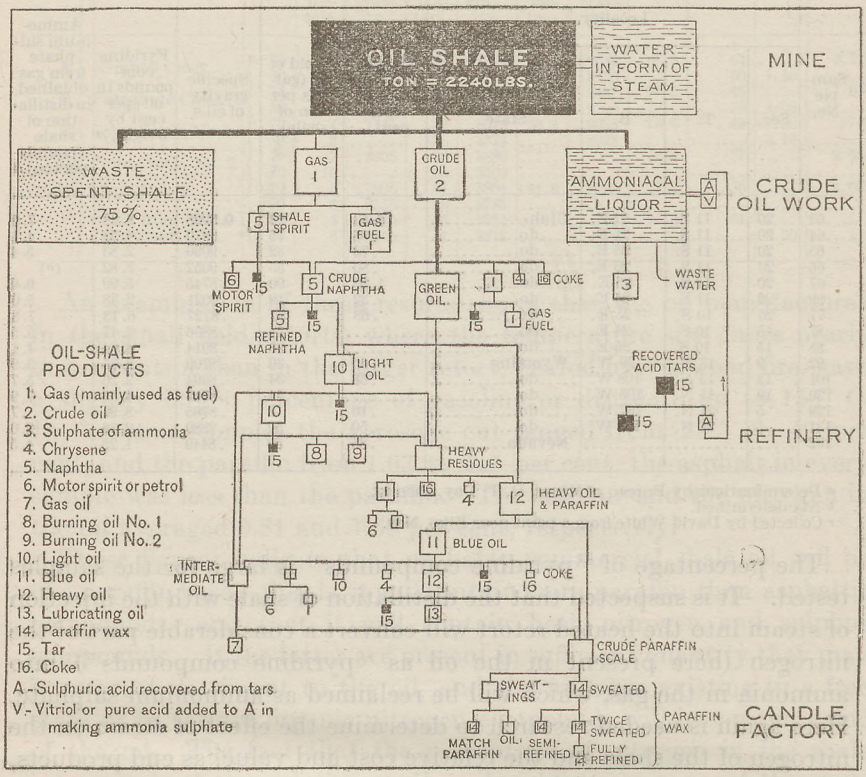

FIGURE 4.—Diagram illustrating processes of manufacture in the Scottish mineral-oil industry.

of gas, the variety of the American products may be large. It is quite probable that products of especial value will be discovered during the chemical research which should precede and accompany the development of an oil-shale industry in the United States.

ORIGIN.

Although the oil shales of different countries and areas vary considerably in character and composition and the oil obtained by the distillation of oil shale may not be derived from the same source, there seems to be ample proof that the oil from the oil shale of the

Green River formation is largely obtained by the destructive distillation of the partly bituminized vegetable matter contained in the shale. It has been argued by some authors[24] that the oil is not indigenous to the shale from which it can be distilled but was formed elsewhere and then migrated to the shale, where it has become adsorbed and inspissated, so that it can not be extracted by solvents of petroleum but must be obtained by destructive distillation.

Steuart[25] has suggested that "kerogen" (the oil-yielding substance of oil shale) has been produced from organic matter by the action of microbes under special circumstances, the products being dependent on the microbe, or that "kerogen" may be the remains of certain kinds of vegetable matter, perhaps little altered, the product being dependent on the kind of original organic material. It is the present writer's opinion that to the type of original material is due, at least in large part, the transformation into oil-yielding substance rather than into coal.

An examination of the shales of the Green River formation has shown that invariably the shale showing the larger percentage of vegetable débris will yield the most oil and vice versa, and that shale beds occurring between beds of rich oil shale may be equally compact and fine grained and yet yield no oil on distillation. There appears to be no reason why oil migrating into the shales should not penetrate all alike, and the oil might be expected to follow the beds of least resistance—that is, the coarser beds of sandstone which are interbedded with the shales. It is true that there are beds of sandstone which are locally saturated with asphalt, but there are also persistent beds of sandstone adjacent to rich oil-shale beds and even lenses of sandstone completely surrounded by good oil shale which show no signs of oil or asphalt. It seems certain that if the oil had migrated into the shale such porous sands would contain at least small quantities of oil that might be obtained by distillation.

That oil as such is present in the Green River oil shale is proved by the odor of petroleum given off by rock that is freshly broken and also by the fact that some oil may be dissolved out of the richer shales by ether, carbon bisulphide, etc., and it is possible that an even larger percentage has existed as oil but is now inspissated and has been adsorbed by the shale particles. The fact that after treatment with carbon bisulphide continuously for a period of three weeks oil shale was still capable of yielding on distillation oil that was not extracted by the solvent indicates that probably earth processes have not completely converted the vegetal matter to petroleum.

[24] Cunningham-Craig, E. H., Origin of oil shale: Roy. Soc. Edinburgh Proc., vol. 36, pp. 44–86, 1916. Coste, Eugene, Oil shales of Elko, Nev.: Am. Inst. Min. Eng. Bull., pp. 1403–1404, 1914.

[25] Steuart, D. R., The chemistry of the oil shales: The oil shales of the Lothians, 2d ed., pt. 3, p. 164, Scotland Geol. Survey Mem., 1912.

In examining the papers of Dr. C. A. Davis since his death the writer discovered the following notes, which indicate his ideas as to the origin of the oil in oil shale after returning from the field in 1914:

RELATION OF BITUMINOUS COMPOUNDS TO MINERAL MATTER IN THE OIL SHALE OF THE GREEN RIVER FORMATION.

[Notes by C. A. Davis, dated Oct. 30, 1914.]

The shale is composed of organic matter, bituminous matter, and mineral matter. The amount of bituminous matter increases as the mineral matter decreases—that is, it increases with the increase of organic matter in the shales. However, it needs only, a casual inspection of the shales in place to see that the beds run very irregular in mineral matter; the rich shales are very compact and almost as impervious as rubber, being made up of what seem to have been partly decomposed remains of minute plants, algae, fungi, spores, pollens, bacteria, etc., embedded as a jelly-like mass; between these there are few, if any, interspaces, and such grains of mineral matter as are present seem to be firmly embedded in this jelly-like mass. Some thin sections show the silt to be exceedingly fine and in thin laminae which are much thinner than the laminae of combustible material of the section. In fact, the mineral part of the rich bed is physically so minute that if it were the sole original material into which the bituminous matter was injected, the intrusion must have greatly distorted the beds overlying the invaded beds, but even where the layers are very thin no such distortion is observable. If the invasion by the bituminous matter occurred while the beds were still forming and the grains were free to move, it would be necessary to assume that the silts were dry, a possibility that seems barred by the great number of algae and other water plants present in the deposit. If the silt and sandy layers were dry it is also difficult to see how the finer, more compact layers absorbed and retained so much more bituminous matter than those containing larger grains and having a large number of capillary interspaces, for although a given volume of clay will hold more water than the same volume of sand, it is evident that the rich beds in these oil shales, volume for volume, contain a vastly smaller amount of mineral matter than the leaner sandy beds. If, on the other hand, the bituminous matter originated in the highly organic beds and has begun to migrate under pressure or other factors, the most obvious place for it to be stored first would be in the adjacent more sandy beds, and from this theory it would be expected that the more sandy beds would yield larger percentages of more volatile petroleum than the others. If, however, the bituminous matter is held in the partly bituminized organic matter seen in an incompletely decomposed state in the shale, heat might decompose the parent fossil material, and petroleum in quantities proportionate to the percentages of the plant remains might be produced, and from both kinds of shale the product would be essentially the same. These facts seem to be developed in reported tests.

OIL-SHALE LAND.

A large part of the valuable oil shale of the western United States is on Government land, at the present time about 896,000 acres in Colorado, 2,696,000 acres in Utah, and 460,000 acres in Wyoming being classified as mineral land chiefly valuable for its oil shale. The lands so classified, with the exception of two relatively small areas, one each in Colorado and Utah, which have been set aside for the use of the United States Navy and comprise only about 3 per cent

of the total area, are open to nonmineral entry (homestead, etc.) in accordance with the act of Congress dated July 17, 1914, and to lease for their oil shale in accordance with the act of Congress dated February 25, 1920. Under the act of July 17, 1914, the mineral deposits in all entries are reserved for separate acquisition under the mineral-land laws, and under the leasing law passed February 25, 1920, a maximum area of 5,120 acres of oil-shale land may be leased by certain individuals or associations of individuals for indeterminate periods upon such conditions as may be imposed by the Secretary of the Interior.

Naval oil shale reserve No. 1, Colorado No. 1, comprises 45,444 acres in Tps. 5 and 6 S., Rs. 94 and 95 W. sixth principal meridian, and lies on the north side of Grand River between Rifle and Grand Valley. Naval oil shale reserve No. 2, Utah No. 1, comprises 86,584 acres in Tps. 12 and 13 S., Rs. 18 and 19 W., and lies between Hill Creek and Green River about 25 miles west of Watson, Utah. (See map, Pl. XVI.)

The following regulations concerning oil-shale leases were approved by the Secretary of the Interior [26] March 11, 1920:

DEPARTMENT OF THE INTERIOR,
GENERAL LAND OFFICE,
Washington, D. C., March 11, 1920.

REGISTERS AND RECEIVERS,
UNITED STATES LAND OFFICES.

SIRS: Section 21 of the act of Congress approved February 25, 1920, entitled "An act to promote the mining of coal, phosphate, oil, oil shale, gas, and sodium on the public domain," authorizes the Secretary of the Interior to lease any deposits of oil shale belonging to the United States, and the surface of such lands as may be necessary for the extraction and reduction of the minerals leased. The following rules and regulations will govern the issuance of such leases:

1. *Qualifications of applicants.*—Pursuant to section 1 of said act, leases may be made to (*a*) a citizen of the United States; (*b*) an association of such citizens; (*c*) a corporation organized under the laws of the United States, or of any State or Territory thereof, provided that no stockholders are citizens of nonreciprocating countries, as provided in section one of the act; or (*d*) a municipality.

2. *Lands and deposits to which applicable.*—The lease may include such deposits and the surface of so much of the land containing same, or of land adjacent thereto, as may be required for the extraction and reduction of the leased minerals, the aggregate area not to exceed 5,120 acres.

Such leases may not include lands or deposits in (*a*) national parks, (*b*) forest reserves created under the act of March 1, 1911 (36 Stat., 961), known as the Appalachian forest reserve act, (*c*) lands in military or naval reservations, (*d*) Indian reservations, or (*e*) ceded or restored Indian lands the proceeds from the disposition of which are credited to the Indians.

All permits or leases for the exploration for or development of oil or gas deposits under this act within the limits of national forests or other reservations, or withdrawals to which this act is applicable, shall be subject to and contain such conditions, stipu-

[26] General Land Office Circ. 671, 1920.

lations, and reservations as the Secretary of the Interior shall deem necessary for the protection of such forests, reservations, or withdrawals, and the uses and purposes for which created.

3. *Form and contents of application.*—Applications for leases must be under oath and should be filed in the proper district land office, addressed to the Commissioner of the General Land Office. No specific form of application is required, and no blanks will be furnished, but it should cover in substance the following points:

(*a*) Applicant's name and address.

(*b*) Proof of citizenship of applicant, by affidavit of such fact if native born; if naturalized, by a certified copy of a certificate thereof in the form provided for use in public-land matters, unless such copy is on file. If the applicant is an association each member thereof must show his qualifications as above stated; if a corporation, a certified copy of the articles of incorporation must be filed, together with evidence that none of its stockholders are citizens of another country the laws, customs, or regulations of which deny similar or like privileges to citizens or corporations of this country; if a municipality a showing of (1) the law or charter and procedure taken by which it has become a legal body corporate; (2) that the taking of a permit or lease is authorized under such law or charter; and (3) that the action proposed has been duly authorized by the governing body of such municipality.

(*c*) A statement that the applicant has no lease under the provisions of this section, nor any other application for lease thereunder pending, and that he does not hold interests in such leases or applications which, with the land applied for, will exceed 5,120 acres.

(*d*) Description of land for which the lease is desired, by legal subdivisions if surveyed, and by metes and bounds if unsurveyed, in which latter case the description should be connected to some corner of the public-land surveys where practicable, or to some permanent landmark. If the land is unsurveyed, the applicant, after he has been awarded the right to a lease, but before the issuance thereof, will be required to deposit with the United States surveyor general of the State where the land is located the estimated cost of making a survey of the lands, any balance remaining after the work is completed to be returned. This survey will be an extension of the public-land surveys over the tract applied for, the leased land to be conformed to legal subdivisions of such survey when made.

(*e*) Evidence that the land is valuable for its oil-shale content, except so much thereof as is necessary for the extraction and reduction of the leased minerals, with a statement as accurate as may be of the character and extent and mode of occurrence of the oil-shale deposits in the lands applied for.

(*f*) Proposed method, so far as determined, as to the process of mining and reduction to be adopted, the diligence with which such operations will be carried on, and the contemplated investment in reduction works and development, and the capital available therefor.

(*g*) The application shall be accompanied by a notice for publication, in duplicate, prepared for the signature of the register, in substantially the following form.

"Serial No. ——. DEPARTMENT OF THE INTERIOR,
U. S. LAND OFFICE AT ———,
——— ———, 19—.

"NOTICE OF APPLICATION FOR OIL SHALE LEASE.

"Notice is hereby given that in pursuance of the act of Congress, approved February, 25, 1920, ——— ——— whose post-office address is ——— has made application for oil-shale lease covering the following described lands: ———.

"Any and all persons claiming adversely any of the above-described lands are required to file their claims in this office on or before ———; otherwise their claims will be disregarded in the granting of such lease.

"———, *Register.*"

The register will fix the time within which adverse or conflicting claims may be filed at not less than 30 nor more than 40 days from first publication.

4. *Disposition of application.*—(*a*) The application will be given the current serial number by the register and receiver, noted on their records, and the notice for publication will be signed by the register.

(*b*) One copy of the signed notice will be delivered to the applicant, who will cause the same to be published in a newspaper to be designated by the register, of general circulation and best adapted to give the widest publicity in the county where the land is situated. If the land is in two or more counties, notice must be published in each. Notice must also be posted in the local land office during the period of publication.

(*c*) At the expiration of the period of publication the application, together with evidence of publication and posting in said office, should be promptly transmitted by the register and receiver to the Commissioner of the General Land Office with a statement of the status of the land involved as to conflicts, withdrawals, protests, and any other matters that may be necessary to determine the availability of the land or deposits therein for lease.

5. *Action on application.*—As the area and form of lands leased hereunder is entirely discretionary with the Secretary of the Interior, if the area applied for is considered too large, or the form unsatisfactory, or in case of conflicting applications, the application may be held for rejection, but the applicant given an opportunity to amend his application in conformity with requirements. Should the application be found satisfactory by the Commissioner of the General Land Office, he will submit it to the Secretary of the Interior with a recommendation that a lease for the described lands be awarded the applicant. If the right to a lease be granted, the applicant will be required, within 30 days from notice, to pay the rental of 50 cents per acre for the first year, which the receiver will carry in his unearned account, until the lease is acted upon, and to furnish a lease duly executed on his part, which lease will be substantially in the following form:

6. *Form of lease.*—

"Serial No. ——. "DEPARTMENT OF THE INTERIOR,
"U. S. LAND OFFICE AT ———.

"OIL-SHALE LEASE.

"*Date—Parties.*—This indenture of lease entered into in triplicate this —— day of ———, 192–, by and between the United States of America, acting in this behalf by the Secretary of the Interior, party of the first part, hereinafter called the lessor, and ——— ———, party of the second part, hereinafter called the lessee, under and pursuant to the act of Congress approved February 25, 1920, entitled 'An act to promote the mining of coal, phosphate, oil, oil shale, gas, and sodium on the public domain,' witnesseth:

"1. *Purposes.*—That the lessor in consideration of the rents and royalties to be paid, and the covenants to be observed as hereinafter set forth, does hereby grant and lease to the lessee the right and privilege to mine and dispose of all the oil shale or the products thereof that may be mined under the terms of this lease from the following-described lands ———, containing ——— acres, together with the right to construct thereon all such works as may be necessary or convenient for the reduction of such shale and the preparation of its oil or other contents for market.

"2. *Subject to limitations of act.*—It is expressly understood that this lease is granted subject in all respects to the conditions, limitations, and provisions of the act under which this lease is made, which act, so far as it relates to oil shale, is hereby made a part hereof to the same extent as if incorporated herein.

"3. *Rights reserved.*—The lessor expressly reserves the right to grant, upon such terms as the Secretary may determine to be just, such easements or rights of way,

including easements in tunnels, upon, through, or in the lands leased, as may be necessary to the working thereof, or of other lands containing coal, oil, oil shale, phosphate, gas, or sodium, and the treatment or shipment of any of the products of such lands by or under authority of the United States, its lessee or permittee, and for other public purposes.

"4. The lessee, in consideration of the lease of the rights and privileges aforesaid, hereby covenants and agrees as follows:

"(*a*) *Investment.*—To invest in mining operations, reduction plants, or other equipment for the mining and reduction of the minerals leased, as follows: That is to say [*Here give detailed description of proposed reduction plant and other equipment or works*], upon the lands included herein the sum of ——— dollars, of which sum not less than one-fifth be expended during the year succeeding the execution of this instrument, and a like sum each year for the succeeding four years, unless such amount may be sooner invested.

"(*b*) *Bond.*—To furnish within thirty days after signature of the lease a bond in the sum of one-half the amount to be expended each year, conditioned upon the expenditure of such sum within said period, and submit annually at the expiration of each year for the said period an itemized statement as to the amount and character of the expenditure during said year.

"(*c*) *Annual rentals.*—To pay as an annual rental, for each acre or part thereof covered by this lease, the sum of fifty cents per acre each year during the life of this lease, all such annual payments of rental to be paid in advance to the receiver of the proper local land office on the anniversary of the date hereof, and to be credited to the first royalties becoming due hereunder during the year for which rental was paid, unless during any of the first five years of the existence of the lease the lessor waives the payment of royalty or rental.

"(*d*) *Royalty.*—To pay to such receiver a royalty of ——— per centum of the market value of the commercially extractable crude oil content, and other primary products of all shale mined and sold or reduced, unless the Secretary of the Interior waives the payment of such royalty during any or all of the first five years of the lease. The lessee agrees to make and keep a record of, by methods and practices satisfactory to the lessor, all necessary gagings, measurements, or analyses of all shale mined and sold or reduced, and all products manufactured therefrom by the lessee, to afford an adequate basis for computing and ascertaining the amount and grade of the crude and other primary products on the basis of which such royalty is to be paid; the decision of the Secretary of the Interior as to the market value of such products on which the royalty is computed shall be conclusive. The royalty must be paid on the last day of March, June, September, and December, each payment to cover the royalty on all production during the preceding three months.

"(*e*) *Reports.*—To keep accurate account of the amount and value of the production under the lease, and to make a report on the last day of March, June, September, and December of the amount and value of the production during the preceding three months; also the amount invested in the property, the cost of operation, contracts in force as to disposal of proceeds, and depreciation of the property used in working the leased land; the books, records, property leased, and reduction works to be subject to inspection at any time by an accredited agent of the lessor.

"(*f*) *Sublease.*—Not to assign this lease or any interest therein, nor sublet any portion of the leased premises, or any of the rights and privileges herein granted without the written consent of the lessor being first had and obtained.

"(*g*) *Diligence.*—To proceed diligently to develop and mine the oil shale upon the leased lands, and extract therefrom the oil and other valuable contents by the most approved methods, and in such a manner as to utilize all of the shale that can be successfully mined, leaving no available mineral abandoned where the mining is being conducted.

"(*h*) *Regulations.*—To comply with such regulations as have been adopted by the Secretary of the Interior and were in force at date of this lease relative to (1) the safety and welfare of the workmen; (2) the prevention of undue waste; and (3) the exercise of reasonable diligence, skill, and care in the conduct of mining operations, which are made a part hereof as fully as if incorporated in this lease; it is also agreed that the workday shall not exceed eight hours for underground workers, except in cases of emergency, prompt report of which must be made to the lessor; that no boy under sixteen years of age, nor any girl or woman shall be employed in any mine below the surface; that the workmen shall have absolute freedom to purchase their supplies wherever they may desire; that wages shall be paid twice each month in lawful money of the United States.

"(*i*) *Interest in leases.*—To observe faithfully the provisions of section twenty-seven of the act, defining the interest or interests that may be taken, held, or exercised under leases authorized by the act.

"5. *Prevention of monopoly.*—The lessor reserves full power and authority to carry out by order, and to enforce all the provisions of section thirty of the act, to insure the sale of the production of such land to the United States and to the public at reasonable prices, and for the prevention of monopoly, and the lessee hereby covenants and agrees to comply with any such reasonable order issued in pursuance hereof.

"6. *Relinquishment.*—The lessee, upon consent in writing of the lessor, may make a written relinquishment of all rights under the lease, and thereupon be relieved of all future obligations hereunder, or he may with like consent surrender any legal subdivisions of the area included herein, upon payment of all rents, royalties, and other debts due and payable to the lessor, and upon payment of all wages or moneys due and payable to the workmen employed by the lessee, and upon a satisfactory showing to the Secretary of the Interior that the public interest will not be impaired; but in no case shall such termination be effective until the lessee shall have made provision for the preservation of any mines or productive works, or permanent improvements on the lands covered by such relinquishment.

"7. *Purchase of improvements.*—On the termination of this lease pursuant to the last preceding section, the lessor, his agent, licensee, or lessee, shall have the exclusive right, at the lessor's election, to purchase at any time within six months, at the appraised value thereof, all buildings, machinery, equipment and tools, or other personalty placed by the lessee in or on the land leased hereunder, save and except underground improvements, machinery, equipment, or structures, which shall be and remain a part of the realty without further consideration or compensation; that the purchase price to be paid for said buildings, machinery, equipment, and tools to be purchased as aforesaid, shall be fixed by appraisal of three disinterested and competent persons (one to be designated by each party hereto, and the third by the two so designated); the valuation of the three or a majority of them to be conclusive; that pending such election to purchase within said period of six months, none of said buildings or other property shall be removed from their normal position; that if such valuation be not requested, or the lessor shall affirmatively elect not to purchase within said period of six months, the lessee shall have the privilege of removing said buildings and other property, except said underground equipment and structures as aforesaid.

"8. *Forfeiture.*—If the lessee shall make default in the performance of any of the terms, covenants, and stipulations of this lease, and such default shall continue after written notice thereof by the Secretary of the Interior or his authorized representative, the lessor may, by appropriate proceedings, have this lease forfeited and canceled in a court of competent jurisdiction, but this provision shall not be construed as depriving the lessor of any legal or equitable remedy which the lessor would otherwise have, A waiver of any particular cause for forfeiture shall not affect the right to proceed against the lessee for any other cause of forfeiture, or for the same cause occurring at any other time.

"9. *Heirs and successors.*—It is further agreed that each obligation hereunder shall extend to and be binding upon, and every benefit hereof shall inure to, the heirs, executors, administrators, successors, or assigns of the respective parties hereto.

"10. *Readjustment of royalties.*—The lessor shall have the right to readjust and fix the royalties payable hereunder at the end of twenty years from the date of this lease, land to so readjust at the end of each succeeding period of twenty years, but the lessee may, if dissatisfied with the royalties imposed, relinquish and surrender this ease in the manner provided in sections 6 and 7 hereof.

"11. *Unlawful interest.*—It is also further agreed that no Member of or Delegate to Congress, or Resident Commissioner, after his election or appointment, or either before or after he has qualified, and during his continuance in office, and that no officer, agent, or employee of the Department of the Interior shall be admitted to any share or part of this lease, or derive any benefit that may arise therefrom, and the provisions of section 3741 of the Revised Statutes of the United States, and sections 114, 115, and 116 of the Codification of the Penal Laws of the United States approved March 4, 1909 (35 Stat., 1109), relating to contracts, enter into and form a part of this lease, so far as the same may be applicable.

"In witness whereof—

"THE UNITED STATES OF AMERICA.
"By ——— ——— [L. S.]
"*Secretary of Interior.*

"Witnesses:
——— ——— ——— ——— [L. S.]''
——— ——— ——— ———
——— ——— ——— ———
——— ——— ——— ———

7. *Preferred right to a lease.*—Under a proviso of section 21 of the act, a person having a valid claim to oil-shale deposits under existing law, prior to January 1, 1919, shall, upon the relinquishment of such claim or claims, be entitled to a lease for not exceeding 5,120 acres, provided "that no claimant for a lease, who has been guilty of any fraud or who had knowledge or reasonable ground to know of any fraud, or who has not acted honestly and in good faith, shall be entitled" to such lease.

The beneficiaries of this proviso are those persons or their grantors who, in the honest belief that the mining laws were applicable to oil-shale deposits, have proceeded in absolute good faith to make mineral locations, lode or placer, of shale deposits, and who have, in all respects, fully complied with the provisions and requirements of such laws, including discovery.

The same form of procedure in making applications for lease should be followed as in other cases, except that, in addition to the points referred to in section 3 of any ordinary application, an application for a preference right lease should be accompanied by a full and detailed showing under oath, duly corroborated, of the facts on which the applicant claims a preferred right, together with copies of the location notices, abstracts of title, and such other evidence as may be deemed necessary to establish the claimant's preferred right and entire absence of fraud. Claimants of such preferred rights to leases should present same promptly; otherwise the lands may be leased to others, in which case any preference rights under this proviso will be deemed to have lapsed.

FEES AND COMMISSIONS.

Under the authority of section 38 of the act, the following fees and commissions are prescribed for transactions under the act:

(*a*) For receiving and acting on each application for a permit, lease, or other right filed in the district land office in accordance with thsee regulations, there shall be paid

a fee of two dollars ($2) for every 160 acres, or fraction thereof, in such application, but such fee in no case to be less than ten dollars ($10), the same to be paid by the applicant and considered as earned when paid, and to be credited in equal parts on the compensation of the register and receiver within the limitations provided by law.

(*b*) A commission of one per cent (1%) of all moneys received in each receiver's office to be equally divided between the register and receiver; such commission will not be collected from the applicant, lessee or permittee, in addition to the moneys otherwise provided to be paid

(*c*) It should be understood that the commission here provided for will not affect the disposition of the proceeds arising from operations under the act as provided in section 35 thereof; also that such commission will be credited on compensation of registers and receivers only to the extent of the limitation provided by law for maximum compensation of such officers.

Very respectfully,

CLAY TALLMAN,
Commissioner.

Approved: March 11, 1920.
ALEXANDER T. VOGELSANG,
Acting Secretary.

Under section 7 of the above regulations provision is made granting preference to those claimants who made mineral entry on lands prior to January 1, 1919, and "who, in the honest belief that the mining laws were applicable to oil-shale deposits, have proceeded in absolute good faith to make mineral locations, lode or placer, of shale deposits, and who have in all respects complied with the provisions and requirements of such laws, including discovery." The recognition of the validity of such claims implies that claimants who have complied with the laws and regulations as mentioned above may elect either to ask for their rights to preference in the leasing of lands covered by their entry or may ask that patent to the lands be issued as under the old law.

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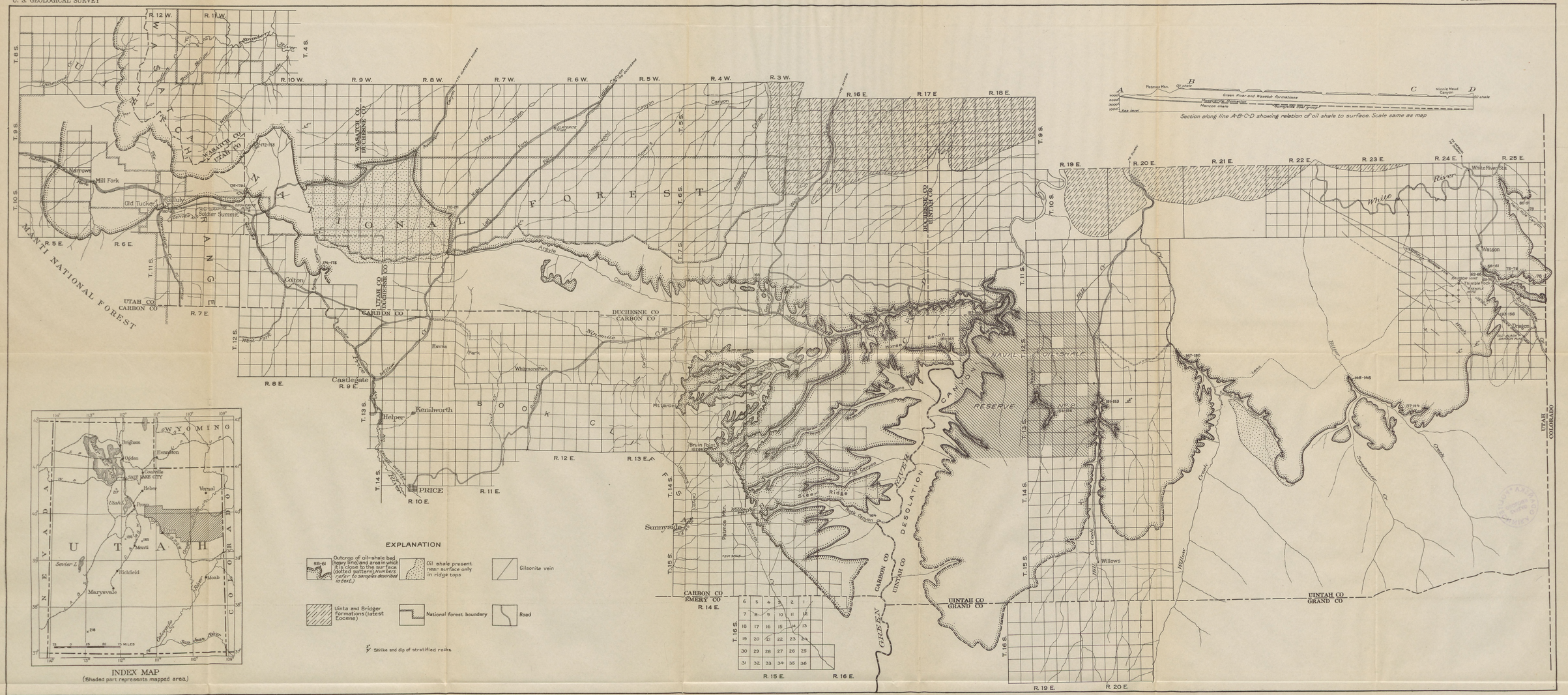

Base compiled from General Land Office plats
Hayden Survey maps, and author's field sheets

MAP SHOWING DISTRIBUTION OF OIL SHALE IN UINTA BASIN, UTAH

By Dean E. Winchester

Scale 1/250,000

0 1 2 3 4 5 10 15

1922

MAP SHOWING DISTRIBUTION OF OIL SHALE IN UINTA BASIN, UTAH

By Donn E. Winchester

Scale

MAP OF PART OF
NORTHWESTERN COLORADO
SHOWING AREAS OF GREEN RIVER FORMATION

By Dean E. Winchester

Scale 1/250,000

5 0 5 10 Miles

Townships shown by solid lines have been surveyed; surveys of other areas are inaccurate

EXPLANATION

- Green River formation (*Contains beds of oil shale in most places*)
- Lava
- Outcrop of oil-shale bed (*Broken line uncertain*)
- Strike and dip
- Point where sample was taken for distillation test. Number refers to list
- fc — Point where fossils were collected
- A x — Measured stratigraphic section. Letter refers to list
- Trail
- 4936 — Approximate surface elevation

MAP OF PART OF NORTHWESTERN COLORADO.

SHOWING AREAS OF GREEN RIVER FORMATION

BY DAVID F. HEWETT.